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CLOSED WASTE DISPOSAL SITE ASSESSMENT TILLSONBURG SANITARY LANDFILL

NOVEMBER 1992

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TILLSONBURG SANITARY LANDFILL

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CLOSED WASTE DISPOSAL SITE ASSESSMENT
TILLSONBURG SANITARY LANDFILL

Report prepared for:

Waste Management Branch
Ontario Ministry of the Environment

Report prepared by:

Terraqua Investigations Ltd.
R. Blackport, A. Pentney

NOVEMBER 1992

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0.0 EXECUTIVE SUMMARY

Terraqua Investigations Ltd. was retained by the Ontario Ministry of the Environment (MOE) to conduct a hydrogeological investigation at the closed Town of Tillsonburg Landfill Site (Certificate of Approval No. 070403). The purpose of the study was to assess the areal extent, depth and type of waste present; to evaluate the geology, hydrogeology and water quality in the vicinity of the site; to identify any existing or potential environmental impacts or risks to human health as a result of the presence of the landfill; and to prepare recommendations with respect to the assessment of remediation options, if any, for the landfill.

A background literature review was undertaken to ascertain the history and general setting of the site. Boreholes were drilled at six locations on-site; groundwater piezometers were installed in five of the holes and landfill gas monitors were installed at six locations within and adjacent to the waste. Four stream-bed piezometers were installed in the creek bed, which is situated at the toe of the slope to the north and east of the landfill site.

The groundwater and stream-bed piezometers were developed, water levels were monitored and response tests were conducted. Two rounds of water samples were collected from the monitors, from leachate seeps at the base of the embankment and from upgradient and downgradient surface water locations along the creek. The samples were analysed for general indicator parameters, and selected samples were analysed for organic priority pollutants.

The background review indicated that the landfill was first issued a provisional Certificate of Approval (No. 071001) in 1971. From 1972 to 1976 annual Certificates of Approval were issued for the site. In 1976 the site was re-numbered as 070403 and the landfill continued to operate until December 1979. The property was described as an excavated borrow pit of clay and sandy soil. The site was authorized to receive 90% domestic waste and 10% solid commercial/industrial waste and construction debris, etc. The site was described as being 2.8 hectares in area and serving a population of about 6500.

Conversations with officials of the Town of Tillsonburg indicated that the waste was expected to fill in the borrow pit, which would have corresponded roughly to the area presently cultivated on-site. The waste was also expected to lie above the water table, and the operation was expected to have conformed to standard landfilling practices of the time.

Initial sampling, undertaken by the Ministry of the Environment in 1978 and in 1980, consisted of two sample rounds of the surface water in a creek adjacent to the landfill. The results of the sampling indicated that the concentrations of some inorganic parameters seemed to increase from upstream of the site to downstream of the site (which suggested the landfill may be impacting the site). The sampling also indicated the presence of phenols in the creek water downstream of the site.

The site area is generally a flat-lying plain which extends south of Tillsonburg. The plain is dissected by several creeks which drain towards Big Otter Creek and then southwest from Tillsonburg. The relief created by the creeks is on the order of 15 metres at the site.

In the general area of the site the overburden geology is expected to be characterized by the presence of the Port Stanley Till (a silty to silty clay till) at surface. The depth to which the till extends is expected to vary. Sand units may underlie (or exist within) the till unit.

The present study indicates that at the landfill (at OW1) a silty to clayey surficial till extends to a depth of 3 metres below ground surface. Underlying the till is a sand unit which extends to a depth of 13 metres below ground surface. A silty sand unit lies below the sand, and extends to a depth of 15 metres below ground surface. A clay unit was encountered below the silty sand.

The drilling program confirmed that the waste was limited to within the presently cultivated area. The waste was encountered to a depth of 13.7 metres below ground surface at the centre of the site. This depth is assumed to be the maximum depth of waste at the site.

The water table was observed to be within the silty sand unit at the site, at a depth of between 11 and 15 metres below ground surface. Horizontal groundwater flow was found to predominate at the site. The groundwater was found to flow from the landfill towards the creek. Horizontal gradients were found to range from

0.01 to 0.06 at the site. A strong upward gradient (on the order of 0.3 to 0.6) was found to exist at the creek, suggesting that a large volume of groundwater discharges into the creek.

Background inorganic groundwater quality was found to be generally good, all parameters within the Ministry of the Environment drinking water guidelines. The landfill impacted groundwaters below the waste and downgradient of the site were found to be significantly elevated above background levels for most inorganic parameters tested. However, the concentrations noted during this study can be considered to be on the low end of the range of concentrations expected from a typical domestic landfill.

The greatest impact was noted in the surface seepage which occurs at the bottom of the embankment between the landfill and the creek. This surface seepage tends to collect in pools along the creek and then flow into the creek. Several organic compound were also noted at parts-per-billion levels in the seepage (and to a lesser extent below the landfill). The organic compounds present seem to be typical for a domestic landfill.

The groundwater quality along the creek was similar to both the background groundwater quality and the surface water quality in the creek. This also would suggest a large groundwater contribution to the creek.

Some inorganic parameters were observed to increase slightly from upstream of the site to downstream of the site. The increase was much less than expected, and generally there seems to be little measurable impact in the creek that is attributable to the landfill. Two organic compounds were noted in the downstream sample in the parts-per-billion range. As yet it is unknown if these compounds are also present at the upstream location.

The results of the gas monitoring program on-site indicate that landfill generated gasses (specifically methane) are present over most of the landfilled area. The levels measured (from 25% to 70%) are considered to be at the upper end of the range typical for domestic landfills. The gasses are not detected in two monitors installed in the embankment along the creek (near the leachate seeps). The presence of methane at the south edge of the landfill (south of the waste, within the sand unit) indicated some potential for off-site migration of gasses at this point. The presence of an industrial site to the south of the site may indicate that further study is warranted to determine the extent of migration in that direction.

As a result of this study several conclusions and recommendations can be made with regard to the landfill impact on the ground and surface waters in the area. The potential health and safety risk due to the present condition of the landfill can also be addressed.

The landfill is observed to directly impact the groundwater below the waste at OW4, OW5 and OW6 and also downgradient of the waste (as indicated by the leachate seep). The levels of most inorganic parameters analysed for at these locations are elevated above both background levels and drinking water standards.

The level of impact observed below the site, however, is not observed to persist into the creek. The observed groundwater discharge directly into the creek (at SB1, SB2, SB3 and SB4) does not show a significant impact from the landfill. Groundwater quality at the creek is observed to be similar to background water quality at the site, and the surface water (creek) is observed to be only slightly impacted by the landfill.

The reason for the lack of observed impact at the creek is not conclusive, however several possibilities exist. Perhaps most of the impacted groundwater is discharged as surface seepage and is diluted to non-detect levels due to the large volume of flow in the creek; or perhaps the impact is diluted to non-detect levels due to cross-flow below the landfill.

This study indicates that there is little impact on either groundwater or surface water usage in the area due to the presence of the landfill. There exists two potential risks to human health or safety due to the presence of the landfill.

One potential risk to human safety is the presence of landfill generated methane at the site. Presently there are no structures which may trap the methane and let an explosive concentration accumulate) on the site itself, and therefore no present risk associated with methane gas production. In the future construction should not be allowed on the landfill site.

Another potential risk to human health and safety is the presence of landfill leachate pools as a result of the surface seepage from the embankment along the creek. In order to reduce the possibility of accidental exposure, some method of limiting public access to the landfill and leachate pools should be considered.

Based on this study it can be recommended that the potential for landfill generated gasses to migrate off-site (specifically southward) should be further investigated. It can also be recommended that some action be taken to limit public access to the landfill and/or leachate pool area along the creek. Also, in order to assess the possible fluctuation during the year of both landfill leachate production and the resulting impact on the creek, a short-term sampling program should be developed.

1.0 INTRODUCTION

Terraqua Investigations Ltd. was retained by the Ontario Ministry of the Environment (MOE), Waste Management Branch, on June 20, 1990, to conduct a hydrogeological investigation at a closed sanitary landfill site in the Town of Tillsonburg, Ontario. The work was performed under Purchase Order No. A-17282.

The site (Certificate of Approval No. 070403) was identified in an inventory of landfills conducted by the Ministry of the Environment (MOE); the inventory made up Phase I of a program designed to investigate and monitor all active and closed waste disposal areas in Ontario. Phase II involved the establishment of a preliminary file and the completion of field investigations to classify the sites and establish priorities for further study.

The purpose of the following study (Phase III) was to assess the hydrogeology of the site and to identify the existence of, or potential for, groundwater or surface water contamination in the vicinity of the site. Additional goals of the investigation were to define any impacts or risks that the site may pose to human health or the environment, and to determine whether detailed investigations of remedial options are required at the Tillsonburg landfill site during Phase IV of the program.

The scope of work included a literature review pertaining to the general site setting and history of the landfill; drilling of six boreholes in the vicinity of the landfill; installation of groundwater piezometers in five of the boreholes; installation of gas monitors at six locations within and adjacent to the waste; installation of four stream-bed piezometers in the bottom of a creek at the toe of the landfill; well development, water level monitoring and response tests; collection and analysis of two rounds of groundwater, surface water and leachate seep samples for general and priority pollutant analysis; monitoring of concentrations of explosive gases within, upgradient and downgradient of the landfill; analysis and interpretation of the data collected; and presentation of the study results.

The following report includes a summary of the history of the landfill site, a description of the study methodology, presentation of the results of the investigation, a discussion of the existing and potential environmental impact related to the landfill, and recommendations regarding any future monitoring or study required at the site.

2.0 HISTORY AND SETTING OF SITE

2.1 GENERAL

The Tillsonburg sanitary landfill, which has been closed since December, 1979, is located on the southern and eastern banks of a stream near the southwestern edge of the Town of Tillsonburg (Figure 1). It is bounded to the south by Baldwin Road and to the west by a railway line (Figure 2). The legal description of the site is the Southern Part of Lot 8, Concession 12, Dereham Township, Oxford County.

A provisional Certificate of Approval (No. 071001) was first issued for the landfill by the MOE in June, 1971; subsequent Certificates of Approval were issued annually for the site from 1972 through to 1976 (when it was re-numbered as site 070403). The property was described in the certificates as an excavated borrow pit of clay and sandy soil, and was authorized to receive 90 % domestic waste and 10% solid commercial/industrial waste and construction debris, etc. The site was described as being 2.8 hectares (7 acres) in area and served a population of about 6500.

Mr. Ken Holland, an official with the Town of Tillsonburg, indicated that, during the time the landfill was in operation, it was leased from its private owner (Mr. Fairs), and was operated by the town, even after the restructuring of the County of Oxford in 1975. Mr. Holland also stated that the bottom of the waste was well above the water table, and that a soil cover was placed between the lifts of the landfill on a weekly basis. Further, a

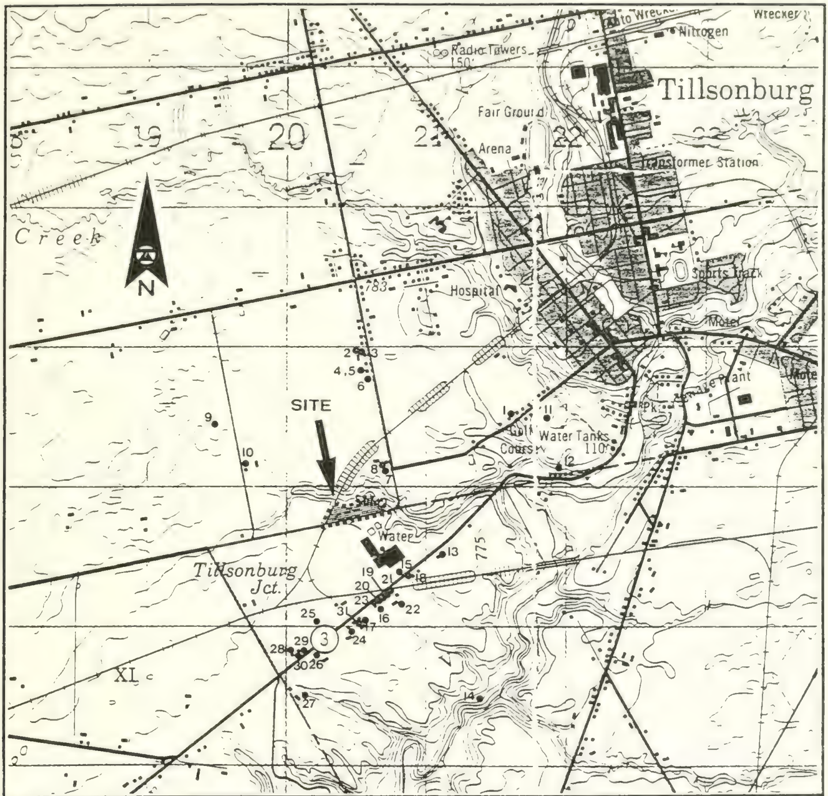

FIGURE 1 LOCATION OF TILLSONBURG LANDFILL No.070403

SCALE

0 500 1000 metres

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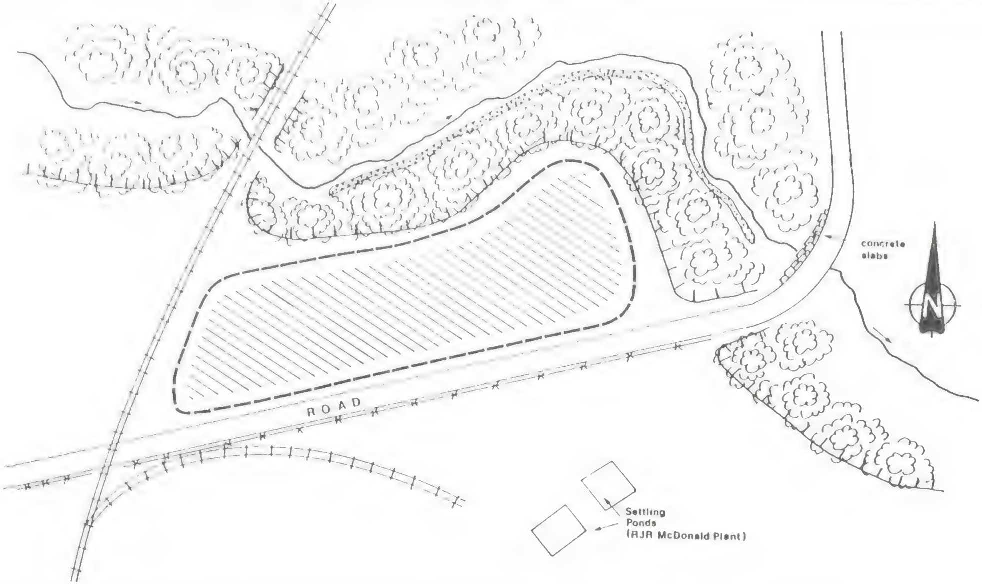
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGIC STUDY
MINISTRY OF THE ENVIRONMENT

LEGEND

▨	Landfill site
2 ●	Location of water well and reference number



LEGEND

- ▭ Approximate extent of landfill
- ▨ Cultivated field
- ✿ Wooded area
- ⌒ Steep embankment
- ⬭ Zone of seepage

SCALE

0 50 100 metres

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TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGIC STUDY
MINISTRY OF THE ENVIRONMENT

FIGURE 2 SITE PLAN

sufficient buffer zone surrounding the landfill had been established, and the waste was apparently kept well away from the steep slope to the north of the site.

Although the majority of the waste in the landfill is expected to be of domestic origin and generally non-hazardous, local residents and business owners have indicated that waste from a firm that used transformers and transformer oil may have been deposited at the site. Other industries, such as a fertilizer plant, the tobacco plant located to the south of the landfill, a woodworking facility, an automotive plant and a plastics plant may have potentially contributed solid waste to the landfill.

However, Mr. R. Brankly of the County of Oxford Engineering Department indicated that a second landfill (070402) was opened to the south of Highway 3 in 1972, and that it received much of the commercial and industrial waste generated in the Tillsonburg area. This second site was closed in 1986, and waste from the County is now disposed of in a central landfill to the northwest of Tillsonburg. A third landfill at the east end of town (070401) also accepted domestic waste, but the life and duration of the landfill is unknown at present.

The site is now owned by Dave Laur Development Inc., and is farmed by the son of the previous owner; a crop of corn was present on-site during the course of the fieldwork. The cultivated area represents the top of the covering fill layer over the waste, and is flat-lying. The embankment down to the creek is quite steep and the creek level is on the order of 15 metres below the upper field level (Figure 2).

Zones of groundwater seepage present near the toe of the south creek bank are approximately 2 metres above the creek bed level. Several leachate seeps and springs were flowing from the bank and into the creek at the time of study (Figure 2). The seepage zone was observed to be very unstable to walk on at this time.

2.2 PREVIOUS STUDIES

A preliminary inspection of the landfill site was undertaken by the Ministry of the Environment in 1978. The inspection involved the collection and analysis of two surface water samples (collected from the creek, upgradient and downgradient of the waste disposal area), and one leachate seep near the east end of the site. In May 1980 another downstream sample was obtained and analysed for an expanded set of parameters. The results of the preliminary chemical analyses are presented in Table 1 and in Appendix A.

The results indicate that, at the time of the first sampling (October or November, 1978), the water chemistry of the creek was noticeably affected by the discharge of leachate contaminated groundwater and seeps from the toe of the slope. While many of the parameters analysed were still within the MOE Drinking Water Objectives in the downgradient surface water sample, levels of iron, chloride, sodium, potassium, free ammonia, TKN, nitrite, BOD and COD were elevated above the concentrations in the upgradient surface water sample

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HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM MOE LABORATORY

PARAMETER	UNIT	OCTOBER 1978			MAY 1980
		UPSTREAM	LEACHATE SEEPAGE	DOWNSTREAM	DOWNSTREAM
GENERAL					
pH		7.93	7.26	7.82	8.05
Conductivity	umho/cm	650	1240	699	
Alkalinity (CaCO)	mg/L	262	682	294	290
Hardness (CaCO)	mg/L	345	752	364	341
BOD	mg/L	0.3	195	4.8	
COD	mg/L	13	329	23	22
Ammonia	mg/L	0.095	0.025	0.285	0.130
Phenols	ug/L				8.0
Phosphorus:	mg/L				
Total	mg/L	0.013	0.021	0.014	0.016
Dissolved Reactive	mg/L	0.009	0.003	0.001	0.001
Carbon:	mg/L				
Total	mg/L				83.0
Inorganic	mg/L				66.0
Organic	mg/L				17.0
ANIONS					
Chloride	mg/L	12.0	27.5	17.0	18.5
Nitrite	mg/L	0.018	0.029	0.083	0.051
Nitrate	mg/L		2.19	1.15	5.95
TKN	mg/L	0.130	0.345	0.570	0.56
Sulphate	mg/L	52	32.0	51	44.0
METALS					
Arsenic	mg/L				<0.001
Molybdenum	mg/L				<.02
Barium	mg/L				0.09
Titanium	mg/L				<0.4
Cadmium	mg/L				<.005
Calcium	mg/L	105	225	109	101
Chromium	mg/L				<.02
Selenium	mg/L				<0.001
Copper	mg/L				<.01
Iron	mg/L	0.1	3.75	0.76	0.08
Lead	mg/L				<.03
Magnesium	mg/L	20.0	46.0	22.0	21.4
Manganese	mg/L				0.19
Vanadium	mg/L				<.02
Zinc	mg/L				<.01
Nickel	mg/L				<.02
Lithium	mg/L				<.005
Silver	mg/L				<.005
Sodium	mg/L	4.2	10.5	7.6	7.2
Potassium	mg/L	1.5	3.60	3.05	2.30

TABLE 1

MOE SAMPLING RESULTS

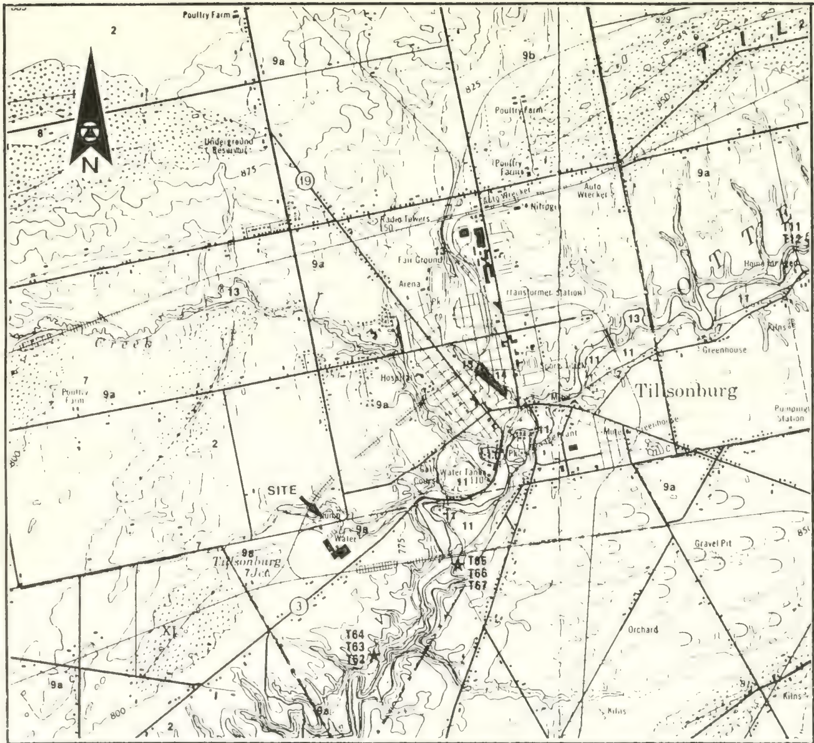
The second sampling of the site (May 1980), although for more chemical parameters, included the downstream location only and therefore an assessment of the impact of the landfill on the stream was not possible. The analyses show no increase in the levels of the parameters sampled for in 1978, however the presence of phenols in the water flowing downstream of the site was noted.

2.3 TOPOGRAPHY AND DRAINAGE

Regionally the site is situated along the northern edge of the flat-lying Norfolk Sand Plain at Tillsonburg (Barnett, 1982). The plain is dissected by various creeks. The pattern of erosion by the creeks provides most of the topographic relief in the the Tillsonburg area. Generally the area slopes gently southeastward.

The site is located approximately 1.5 kilometres northwest of Big Otter Creek, and is bounded to the north and east by a tributary of Big Otter Creek, referred to in this report as the creek. The landfill area (presently cultivated) is flat-lying, at an elevation similar to the surrounding area. The creek has created a valley on the order of 15 metres deep along two edges of the landfill site.

Drainage follows the course of the network of creeks in the area (Figure 3). Locally the site surface drainage is northeast to eastwards towards the creek. Surface water flow is then eastwards towards Big Otter Creek. Big Otter Creek flows



LEGEND

QUARTERNARY - RECENT

14	Cultural features deposits: earth fill
13	Modern alluvium: clay, silt, sand, muck
12	Bog deposits: muck, peat, or marl

PLEISTOCENE

LATE WISCONSINAN

11	Older alluvium terrace remnants: fine to med. sand with occasional pebbles
10	Glaciolacustrine beach or bar deposits: gravel to gravelly coarse sand
9	Glaciolacustrine shallow water and deltaic deposits slightly modified by wind. a.fine to medium sand b.sand containing occasional pebbles
8	Glaciolacustrine deepwater deposits: massive to laminated silt, minor clay
7	Glaciolacustrine deepwater deposits: massive to laminated clay, minor silt
6	Glaciofluvial outwash and deltaic deposits: gravel and gravelly sand
5	Glaciofluvial outwash and deltaic deposits: sand
4	Glaciofluvial ice-contact stratified drift: morainic or kame sand and gravelly sand
3	Wentworth Till: silt till
2	Port Stanley Till: silt to silty clay till
1	Catfish Creek Till: stony sandy silt till

SCALE

0 1 2 kilometres

Source: Quaternay Geology of the Tillsonburg Area
Geological Report 220, Map 2473, 1977
Scale 1:50,000

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HYDROGEOLOGIC STUDY
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FIGURE 3 SURFICIAL GEOLOGY

southwest from Tillsonburg.

2.4 REGIONAL GEOLOGY

The Quaternary geology of the area has been mapped by Barnett (1982). The site is mapped as being located on Port Stanley Till, a silt to silty clay till (Figure 3). Outcropping along the creek and southeast of Big Otter Creek are fine to medium sand units. Southeast of Big Otter Creek the sands are derived from glaciolacustrine shallow water and deltaic deposits which may have been slightly modified by wind, and are geologically more recent than the Port Stanley Till. Along the creek the sand deposits may represent sand units deposited prior to or in conjunction with the Port Stanley Till. Barnett delineates wedge-shaped bodies of sands within the Port Stanley drift (deposited contemporaneously with the Port Stanley Till) near Tillsonburg. The surficial till is shown as overlying sand units which may outcrop in creek valleys or to the north.

Local water well records, covering an area within approximately 1.5 kilometres of the site, generally agree with this mapping (Table 2). Alternating clay (till) and sand units of variable thickness are commonly reported in the area.

The site, then, is characterized as having surface occurrences of Port Stanley Till with underlying sand and/or till unit(s) of variable thickness. Total overburden thickness in the area is on the order of 45 to 55 metres

TABLE 2 SELECTED LOCAL MOE WATER WELL RECORDS

TA30242
TILLSONBURG CLOSED LANDFILL

TERRAQUA REFERENCE NUMBER	MUNICIPALITY CONCESSION ETC.	LOT	UTM EASTING NORTHING	ELEVATION (FEET)	DATE	CASING DIAMETER (INCHES)	KIND OF WATER	WATER FOUND (FEET)	STATIC LEVEL (FEET)	TEST RATE (GPM)	TEST TIME (HR/MN)	WATER USE	OWNER LOG SCREEN	FORMATION INTERVAL (IN FEET)
OXFORD CO., DEREHAM TWP														
1	CON 12	6	521600 4744500	755	12/59		FR	47	25	5	03/00	DO	JACKSON R	
													PRDG	4
													YLLW MSND	18
													REY CLAY	47
													MSND	51
2	CON 12	8	520505 4745000	785	07/60	2	FR	18	18	5	00/30	DO	HORVATH	
													TPSL	4
													CLAY	12
													FSND	18
													MSND	38
3	CON 12	8	520540 4744970	775	09/59	1	FR	14	14	6	00/30	DO	MOUNTENAY R	
													CLAY	14
													CSND	25
4	CON 12	8	520550 4744825	785	11/63	3	FR	35	32	3	01/00	DO	CHANYI W	
													BLUE CLAY	35
													FSND	63
													CSND	64
5	CON 12	8	520570 4744820	785	09/60	5	FR	50	20	8	10/00	DO	FERGERSON A	
													CLAY	12
													YLLW MSND	50
													MSND	55
6	CON 12	8	520585 4744770	785	01/60	5	FR	38	27	7	02/00	DO	FAIRS F	
													CLAY	8
													CLAY MSND	30
													CLAY	38
													MSND	54
7	CON 12	8	520715 4744130	775	07/58	4	FR	64	46	5	04/00	ST DO	FAIRS W	
													TPSL MSND	20
													CLAY	58
													MSND	68
8	CON 12	9	520720 4744150	778	05/72	5	FR	40	30	9	02/30	ST	FAIRS M	
													TPSL	2
													RED CLAY	10
													RED SAND	40
													CSND	48

TABLE 2 SELECTED LOCAL MOE WATER WELL RECORDS (CONTINUED)

TA90242
[illegible]

TERRAQUA REFERENCE NUMBER	MUNICIPALITY CONCESSION ETC.	LOT	UTM EASTING NORTHING	ELEVATION (FEET)	DATE	CASING DIAMETER (INCHES)	KIND OF WATER	WATER FOUND (FEET)	STATIC LEVEL (FEET)	TEST RATE (GPM)	TEST TIME (HR/MN)	WATER USE	OWNER LOG SCREEN	FORMATION INTERVAL (IN FEET)
OXFORD CO., DEREHAM TWP														
4	CON 12	10	519500 [illegible]	790	06/60	5	SU	170	20				PVC	
													YLLW CLAY STNS	19
													YLLW MSND	30
													MSND	77
													CLAY STNS	85
													CLAY	169
													LMSN	170
10	CON 12	10	519700 [illegible]	775	04/62	5	FR	40	27	5	03/00	DO	HAY R	
													YLLW CLAY	20
													YLLW MSND	40
													MSND	56
[illegible] CO., TILLSONBURG TOWN														
11			521875 [illegible]	735	01/55	8	SU	130	FLW			IR	TILLSONBURG GOLF	
													CLAY	2
													HPAN	5
													CLAY	30
													CLAY STNS	64
													GREY LMSN	130
12			521940 4744100	675	01/60	8	SU	40	FLW	5	99/59	DO	COCKBURN H	
													CLAY	40
													RED BLDR	41
NORFOLK CO, MIDDLETON TWP														
13	TRN 4	4	 4743425	777	06/66	5	FR	68	53	3	06/00	DO	KENNEDY	
													YLLW CLAY	18
													SAND	47
													GREY CLAY	68
													FINE SAND	83
14	TRN 5	3	521400 4742400	640	07/76		SU	76	12	10	00/10	DO	REDLING J	
													RED CLAY	14
													GREY CLAY	76
													BLACK SHALE	76
15	TRN 5	3	520800 4743360	760	11/79	7	FR	63	30	40	05/00	IN	RJR MACDONALD INC	
													YLLW CLAY	18
													GREY CLAY	58
													GREY SAND	80

TABLE 2 SELECTED LOCAL MOE WATER WELL RECORDS (CONTINUED)

TA90242
TILLSONBURG CLOSED LANDFILL

TERRAQUA REFERENCE NUMBER	MUNICIPALITY CONCESSION ETC.	LOT	UTM EASTING NORTHING	ELEVATION (FEET)	DATE	CASING DIAMETER (INCHES)	KIND OF WATER	WATER FOUND (FEET)	STATIC LEVEL (FEET)	TEST RATE (GPM)	TEST TIME (HR/MN)	WATER USE	OWNER LOG SCREEN	FORMATION INTERVAL (IN FEET)
16	TRN 5	3	520700 4743150	780	06/71	4	FR	73	40	3	10/00	DO	HALWAS W	
													TPSL	2
													GREY FSND	8
													BLUE CLAY	40
													GREY SAND	50
													CLAY	73
													GREY SAND	81
17	TRN 5	3	4743250	780	11/65	5	SU	170	25	5	36/00	DO	KENNEDY C	
													TPSL	4
													BLUE CLAY	15
													GREY SAND	28
													BLUE CLAY	38
													SAND	95
													CLAY	170
													GRVL	170
18	TRN 5	3	520900 4743370	780	06/61	5	FR	86	62	2	03/00	DO	BENTLY R	
													YLLW SAND	5
													GREY CLAY	10
													YLLW SAND	86
													FSND	91
19	TRN 5	3	4743265	780	09/59	5	FR	59	40	2	99/59		KENNEDY C	
													CLAY	59
													FSND	70
20	TRN 5	3	4743260	780	09/57	5	FR	74	51	5	02/00	DO	BLYTH A	
													CLAY	48
													SAND	86
21	TRN 5	3	520730 4743250	780	11/53	4	FR	90	26	1.5	48/00	DO	HARRY DINK	
													BLUE CLAY	60
													SAND	62
													GREY CLAY	90
													CSND	98
22	TRN 5	3	4743150	780	10/51	4	FR	84	55			DO	WHITESELL C	
													CLAY	40
													SAND	84
23	TRN 5	3	520650 4743160	780	04/48	2	FR					DO	PEARSON H	
													CLAY	10
													SAND	72

TABLE 2 SELECTED LOCAL MOE WATER WELL RECORDS (CONTINUED)

[illegible]
TILLSONBURG CLOSED LANDFILL

TERRAQUA REFERENCE NUMBER	MUNICIPALITY CONCESSION ETC.	LOT	UTM EASTING NORTHING	ELEVATION (FEET)	DATE	CASING DIAMETER (INCHES)	KIND OF WATER	WATER FOUND (FEET)	STATIC LEVEL (FEET)	TEST RATE (GPM)	TEST TIME (HR/MN)	WATER USE	OWNER LOG SCREEN	FORMATION INTERVAL (IN FEET)
24	TRN 5	2	5205[illegible] 474[illegible]100	780	05/77	5	FR	81	49	8	02/30	DO	REDLING J	
													CLAY	42
													SAND	72
													CLAY	81
													SAND	89
25	TRN 5	2	474[illegible]	790	12/62	1.25	FR	50	50	5	01/00	DO	SANDERS L	
													PRDG	50
													SAND	66
26	TRN 5	1	520200 474[illegible]600	800	10/73	2	FR	51	42	5	02/30	DO	BRUNEKREEFT G	
													CLAY	14
													BLDRS	16
													SAND	20
													CLAY	59
													SAND	62
27	TRN 5	1	520150 4742550	780	03/76								PUC TILLSONBURG	
													CLAY	1
													SAND	22
													CLAY	109
													SILT	111
													CLAY	185
													LMSN	187
28	TRN 5	1	474[illegible]770	790	06/64	5	FR	72	51	3.5	48/00	DO	HOLMES P	2
													CLAY	35
													SAND	45
													SAND AND CLAY	72
													SAND	80
													CLAY	80
29	TRN 5	1	4743[illegible]20	797	09/63	5	FR	91	32	5	48/00	DO	METSELAAR A	
													CLAY	34
													SAND	41
													BLUE CLAY	43
													SAND	87
													BLUE CLAY	91
													CSND AND GRVL	98
30	TRN 5	1	474[illegible]50	790	05/62	5	FR	65	41	5	03/00	DO	KELLY F, PROSE E	
													CLAY	30
													SAND	77

TABLE 2 SELECTED LOCAL MOE WATER WELL RECORDS (CONTINUED)

TA90242
TILLSONBURG CLOSED LANDFILL

TERRAQUA REFERENCE NUMBER	MUNICIPALITY CONCESSION ETC.	LOT	UTM EASTING NORTHING	ELEVATION (FEET)	DATE	CASING DIAMETER (INCHES)	KIND OF WATER	WATER FOUND (FEET)	STATIC LEVEL (FEET)	TEST RATE (GPM)	TEST TIME (HR/MN)	WATER USE	OWNER LOG SCREEN	FORMATION INTERVAL (IN FEET)
31	TRN 5	1			10/83	5	FR	54	40	12	01/00	DO	MEYER R	
													TPSL	1
													SAND	10
													CLAY	35
													SAND	62

NOTE : WHERE UTM EASTINGS OR NORTHINGS ARE ABSENT, WELL LOCATION DETERMINED USING DIAGRAMS PROVIDED ON ORIGINAL WELL RECORDS

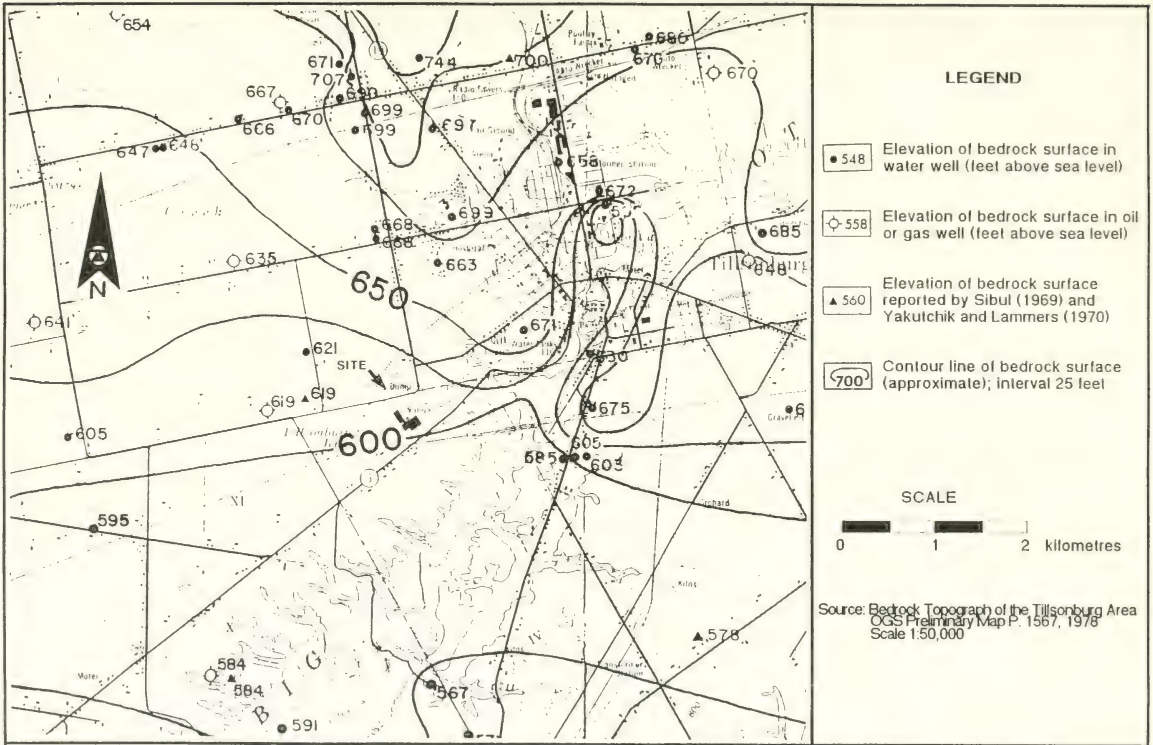
The limestone of the Dundee formation subcrop the area. Bedrock topography slopes gradually southward, with bedrock surface elevations on the order to 190 to 183 metres (600 to 625 feet) above sea level at the site (Figure 4).

2.5 REGIONAL HYDROGEOLOGY

The regional hydrogeology is expected to be controlled by the presence (or absence) of the till and sand units, both at surface and at depth, along with the drainage patterns. The sand units, which are of variable depth and areal extent in the area, will act as aquifers. The actual thickness and continuity of each aquifer will determine the respective water bearing potential. The till units will act as aquitards, and when present at surface will tend to slow both infiltration and the migration of contaminants into underlying aquifers.

According to water well records (Table 2 and Figure 1) water bearing horizons occur near the site at elevations between 210 and 224 metres above sea level. The resulting static water levels range from 221 to 230 metres above sea level. A map of susceptibility of groundwater to contamination produced by the MOE (Figure 5) indicates that to the southeast of the site, on the Norfolk Sand Plain, water bearing horizons are generally closer to the surface.

Generally shallow groundwater flow is expected to be towards the creeks which dissect the plain. Horizontal groundwater movement is expected to be predominant in the shallow zone. At drainage


654
671
707
698
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744
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668
668
685
635
663
648
650
641
671
621
SITE
630
619
619
675
605
600
605
585
603
595
578
584
584
567
591
N
LEGEND
548 Elevation of bedrock surface in water well (feet above sea level)
558 Elevation of bedrock surface in oil or gas well (feet above sea level)
560 Elevation of bedrock surface reported by Sibul (1969) and Yakutchik and Lammers (1970)
700 Contour line of bedrock surface (approximate); interval 25 feet
SCALE
0
1
2 kilometres

Source: Bedrock Topograph of the Tillsonburg Area
OGS Preliminary Map P. 1567, 1978
Scale 1:50,000

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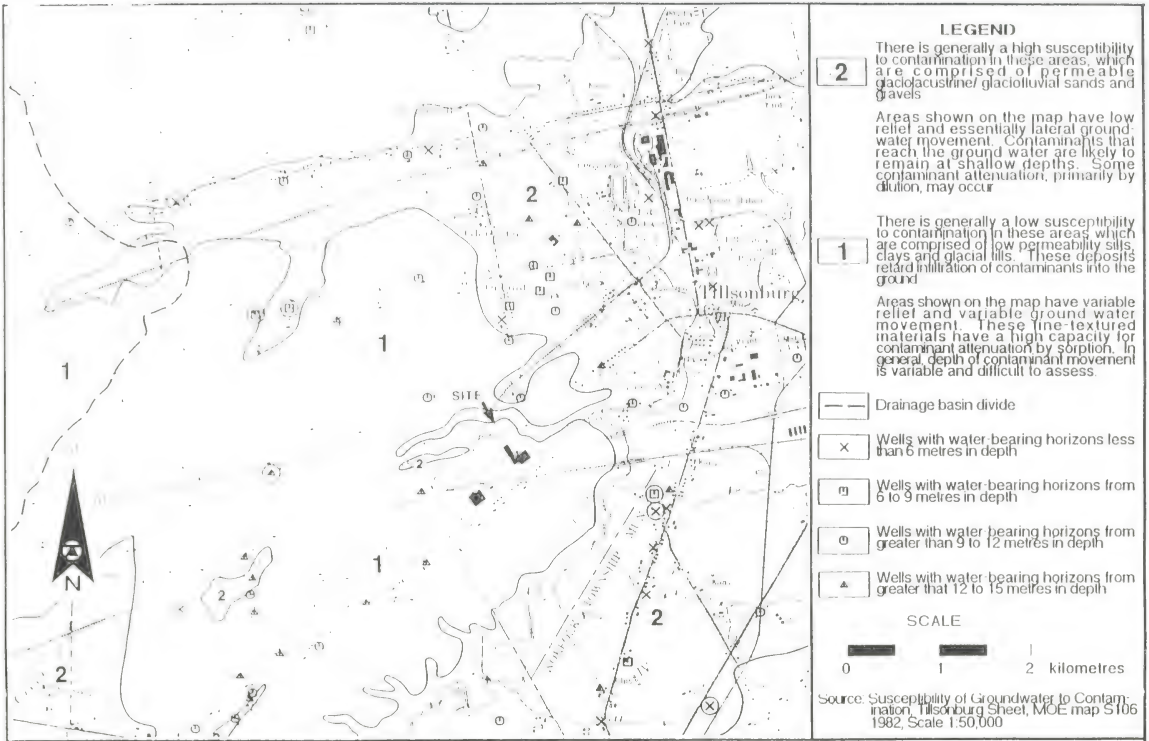
FIGURE 4 BEDROCK TOPOGRAPHY



LEGEND

2 There is generally a high susceptibility to contamination in these areas, which are comprised of permeable glaciolacustrine/ glaciofluvial sands and gravels

Areas shown on the map have low relief and essentially lateral groundwater movement. Contaminants that reach the ground water are likely to remain at shallow depths. Some contaminant attenuation, primarily by dilution, may occur

1 There is generally a low susceptibility to contamination in these areas which are comprised of low permeability silts, clays and glacial tills. These deposits retard infiltration of contaminants into the ground

Areas shown on the map have variable relief and variable ground water movement. These fine-textured materials have a high capacity for contaminant attenuation by sorption. In general, depth of contaminant movement is variable and difficult to assess.

— — Drainage basin divide

× Wells with water-bearing horizons less than 6 metres in depth

Wells with water-bearing horizons from 6 to 9 metres in depth

Wells with water-bearing horizons from greater than 9 to 12 metres in depth

▲ Wells with water-bearing horizons from greater that 12 to 15 metres in depth

SCALE

0 1 2 kilometres

Source: Susceptibility of Groundwater to Contamination, Tillsonburg Sheet, MOE map S106 1982, Scale 1:50,000

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FIGURE 5 SUSCEPTIBILITY OF GROUNDWATER TO CONTAMINATION

divides and at depth (at or near bedrock), some vertical component of flow is expected. The regional bedrock flow (and possibly deep overburden flow) is expected to be southward, following both the general surface and bedrock topography.

The shallow zone will be recharged mainly through infiltration into outcropping sand units. Where there is a till unit at surface, recharge into underlying sand units will be much lower.

2.6 GROUNDWATER USAGE

Private water supply wells are common in the area. Most drilled wells in the area are located in sand units at intermediate depth (between 12 and 24 metres below ground surface). Few wells in the area extend into bedrock. Dug wells are expected to be relatively rare in the area. The depth to water commonly reported in water well records of greater than 6 metres below ground surface precludes the use of dug wells for domestic supply.

Most wells are listed as being for domestic or stock supplies. Out of 31 well records examined (within approximately 1.5 kilometres of the site), two were listed as for industrial or irrigation supply wells (reference numbers 11 and 15). Two Public Utilities Commission (PUC) wells, of indeterminate status, exist within 1.4 and 1.2 kilometres of the site (reference numbers 9 and 27). Both PUC wells extend to bedrock, and one is listed as producing sulfurous water.

The closest wells to the site are the Fairs domestic and stock supply wells located to the north of the site (reference numbers 7 and 8), and the RJR McDonald industrial supply well located south of the site (reference number 15).

The water wells in the area commonly produce from 2 to 5 IGM. Several wells are listed as producing approximately 10 IGM, and the RJR McDonald industrial well is listed as producing 40 IGM.

3.0 STUDY METHODOLOGY

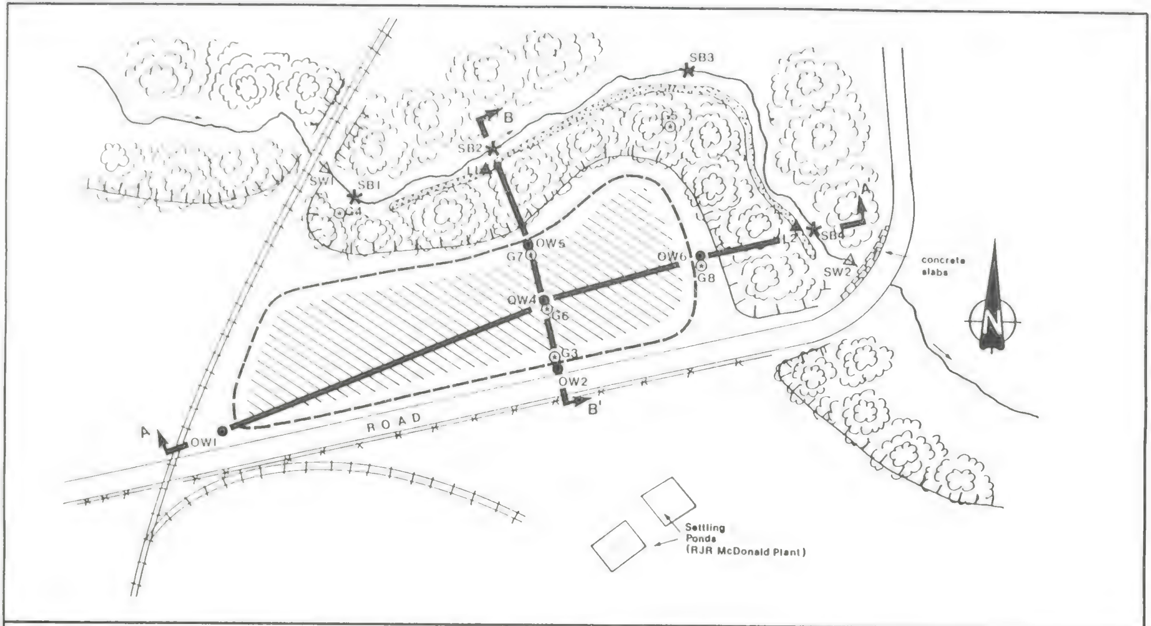
3.1 DRILLING

A total of 6 boreholes were drilled at five locations across the study site (Figure 6). The number of boreholes completed was one less than projected in the proposal as a result of the extent of waste and depth to water table being significantly deeper than the background information suggested. It was necessary to drill the boreholes deeper than anticipated to reach the water table. For this reason the borehole at proposed location OW3 (Figure 6) was eliminated.

The boreholes were completed using a truck-mounted CME-75 rig equipped with 11.5 centimetre I.D. hollow stem augers. Split spoon samples, collected at 1.5 metre intervals where possible, were used to establish the geologic profile. Split spoon samples were generally not attempted within the waste, auger samples were used more often to establish the extent and composition of the waste. The samples were described in the field and all samples of native material encountered were collected in sample bags for future reference. Waste samples were not collected.

3.2 MONITOR INSTALLATION

In the six boreholes drilled, a total of 5 groundwater and 4 methane gas monitors were installed. Groundwater monitors only were installed in the first two holes. After the first two holes were completed it was determined that the number of drilling



LEGEND

OW1 ● Groundwater Monitor
SB1 ★ Streambed Piezometer
G3 ⊙ Gas Probe
L1 ▲ Leachate Sample
SW1 △ Surface Water Sample

Approx. extent of landfill
Cultivated field
Wooded area
Steep embankment
Zone of seepage

SCALE

0 50 100 metres

FIGURE 6 MONITOR AND SAMPLING LOCATIONS

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locations would have to be reduced. In order to maximize the use of the remaining drilling locations, both groundwater and gas monitors were installed in three subsequent boreholes. The final borehole was used to install a gas monitor at the second drilling location.

3.2.1 Groundwater Monitors

The groundwater monitors were constructed of pre-cleaned and bagged 5 centimetre (I.D.) flush-joint threaded PVC casing and 1.5 metre or 3 metre lengths of slotted PVC screen. The monitors were installed through the hollow stem augers at appropriate depths. Where possible a sand pack (using either No.1 or No.3 size silica sand) was installed within the borehole annulus to a height above the top of the screen. A bentonite seal, of a minimum thickness of 0.5 metres, was placed above the sandpack. The hole was backfilled with native material and a surface bentonite seal was installed. Protective casings were cemented into place at ground surface.

3.2.2 Methane Monitors

The methane monitors were constructed of 1.3 centimetre diameter CPVC tubing slotted by hand and capped at both ends. The monitor was slotted in the interval starting at 1.5 metres below ground surface and extending to the bottom of the monitor. The methane monitors were installed above water table, and within any waste encountered in the borehole. In the case of boreholes with both gas and water monitor installations, the gas monitor was installed above the lower seal of the groundwater monitor, and above the water table. All gas monitor holes were sealed at ground surface with bentonite. Two gas monitors were installed along the side slope of the landfill in hand-augered holes and placed just above the water table. Each auger hole was filled with No. 3 size silica sand and sealed at surface with bentonite. The gas monitors were equipped with caps at surface to contain any gasses within the monitor and prevent the venting of landfill generated gasses to the atmosphere.

3.2.3 Stream Bed Piezometers

Four stream-bed piezometers were installed along the creek to the north and northeast of the landfill. The piezometers were constructed of 3.8 centimetre diameter PVC casing fitted with modified Casagrande type drive-points. The slotted interval of the drive point was covered with a 50-micron sleeve to prevent fine grained material from entering the piezometer. The tip was driven into the ground to a depth of approximately 1.9 metres below the stream bed. Each monitor was allowed to extend approximately 1.2 metres above the stream bed.

3.3 WELL DEVELOPMENT

The groundwater monitors installed in the landfill area were developed using the respective dedicated bailers installed in each well. To develop the wells approximately 10 bore-volumes of water were removed from each monitor. The development of the wells removed as much silt and auger cuttings as possible from the screen, and ensured that representative water samples could subsequently be obtained.

The stream bed piezometers were developed using a WaTerra pump which was rinsed with distilled water between each well to ensure against cross-contamination. The piezometers were developed until the discharge water was observed to be free of silt (between 5 and 10 bore volumes removed).

3.4 WELL LEVEL MONITORING AND RESPONSE TESTING

Following the development of the monitoring wells, water levels were measured and response tests completed. Water levels were measured as depth to water below the top of the PVC casing, using a battery operated water level probe. The water levels were monitored daily during the course of the field work, and monthly thereafter. The response tests were performed by using the dedicated bailers or WaTerra pump to purge each well and the water level probe to measure well recovery. A level survey of the ground surface and top of well casing elevations at each monitor was completed. The survey allowed the measured water levels to be expressed as relative elevations.

3.5 WATER SAMPLING

Groundwater, leachate seep, and surface water samples were obtained during this study.

The groundwater samples were obtained following well development using the dedicated bailers, or in the case of the stream bed monitors using a WaTerra pump rinsed between wells. Two leachate samples were collected from the leachate seeps located at the base of the embankment bordering the creek. A composite of the two samples was submitted for analysis. Two surface water locations were sampled (along the creek) during a period of normal stream flow.

The samples were placed in specially prepared sample bottles provided by the laboratory. The samples were kept cool and submitted for analysis as soon as possible after collection (within 24 hours).

3.6 GAS MONITORING

The landfill gas monitoring program was initiated in February 1991. At this time weather conditions were cool enough to freeze the upper cover layer overlying the landfill. The frozen ground establishes a "cap" which would contain any landfill generated gasses and allows for a more accurate determination of the amount of gas produced.

A methane measuring device (explosimeter) was used to measure gas concentrations at each of the gas monitor locations. The unit used was a BACHARACH Gas-Pointer (model H) Combustable Gas Indicator which was calibrated to methane gas. The surface cap of the monitor was removed and the explosimeter was quickly attached directly to the monitor pipe. A sample of the gas within the monitor was drawn up into the explosimeter and the concentration of methane was measured and recorded. After the reading was taken, the monitor cap was replaced to prevent landfill gasses from venting to the atmosphere.

4.0 RESULTS

4.1 SITE GEOLOGY

The borehole logs and monitoring well installation details are presented in Appendix A. The logs are summarized in Table 3, and presented in cross-section format in Figures 7 and 8.

Generally, as can be seen in Figures 7 and 8, at the site a thin layer of clayey to silty material is found at surface. This material represents the cover layer placed over the landfill, and may consist of the reworked native till unit (removed at the time of excavation and replaced after landfilling).

At drilling location OW1, which is considered to represent native conditions, a clean fine sand unit was encountered from 3.3 to 13.4 metres depth. A silty fine sand unit was encountered from 13.4 to 15.2 metres depth, under which lies a silty clay unit from 15.2 metres to the bottom of the borehole at 15.5 metres depth.

This general sequence was generally confirmed by the other four drilling locations, with a few exceptions. At OW4 and OW5 waste was found to "replace" parts of the sand unit. Also, the contact between the sand and silty sand appears to be gradational at OW6.

The former borrow pit excavation seems to coincide with the extent of the sand unit. The excavation would also seem to be limited to above the water table, although the exact depth to water and depth of excavation is unknown between OW4 and OW1.

BOREHOLE	COVER THICKNESS (metres)	WASTE THICKNESS (metres)	DEPTH TO WATER TABLE (metres)	TOTAL DEPTH (metres)	SUMMARY OF OVERBURDEN MATERIAL
OW1	NE	NE	11	15.5	Fine sand to 13.4 m. Silty fine sand to 15.2 m. Silty clay to 15.5 m.
OW2	4.3	NE	13.7	17.1	Silty clay fill to 4.3 m. Fine sand to 13.4 m. Silty fine sand to 17.1 m.
OW4	0.9	12.8	15.2	18.3	Silty clay fill to 0.9 m. Waste to 13.7 m. Silty fine sand to 18.0 m.
OW5	1.8	5.8	15.2	18.9	Silty clay fill to 1.8 Waste to 7.6 Fine sand to 13.7 Silty fine sand to 16.7 Silt to 18.9
OW6	NE	NE	12.2	15.5	Silty clay to 2.7 Fine sand to 4.3 Layered silt and sand to 14.9 Clay to 15.5

NE = Not Encountered

TABLE 3 SUMMARY OF DRILLING RESULTS

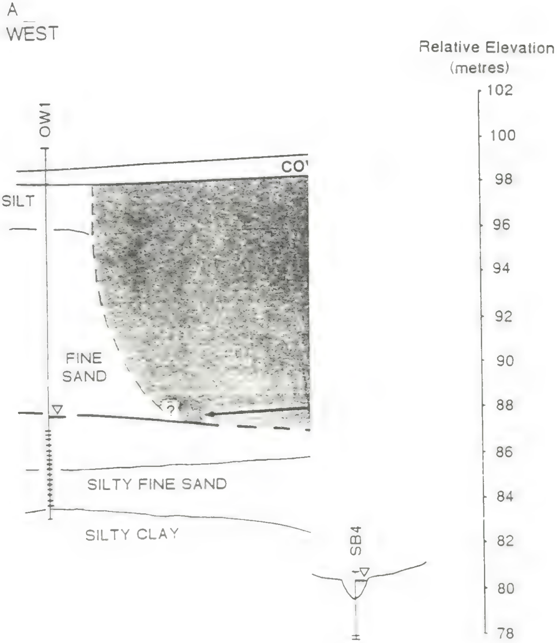
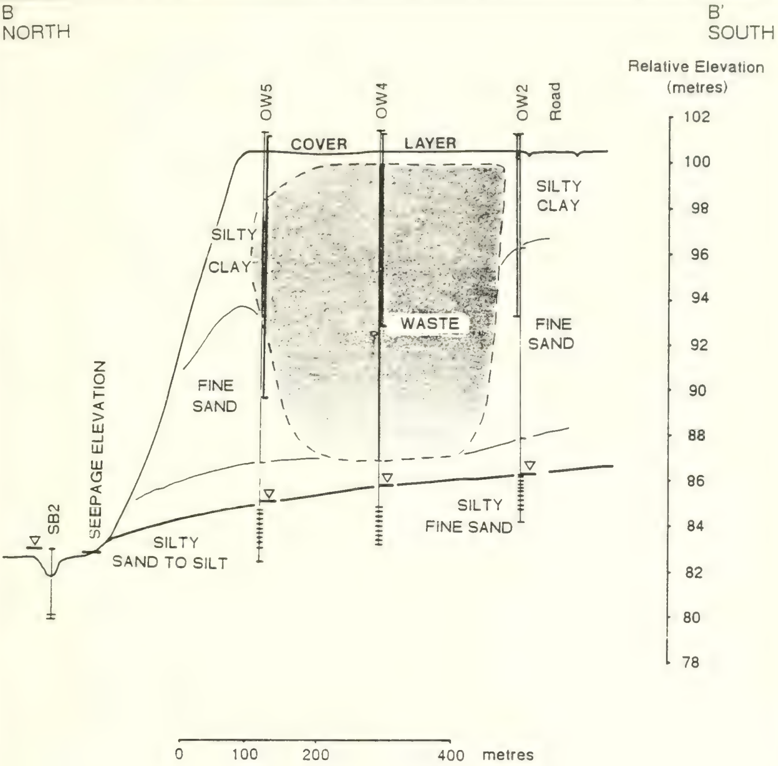


FIGURE 7 CROSS SECTION A - A'



OW1 - TOW
assumed to be @100.000 m

FIGURE 8 CROSS SECTION B - B'

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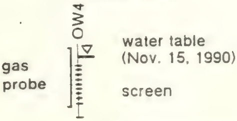
LEGEND

Observation Well



4.2 LOCATION AND EXTENT OF WASTE

The waste was found to consist of mixed domestic and construction waste. Typical materials encountered were: plastics, rubber, cardboard, metal (cans, springs, etc.), an oil filter, decaying vegetable matter, wood, drywall, etc. Within the waste several layers of clayey material were observed. These layers would correspond to the cover material placed over each "lift" within the landfill. The waste may contain other materials not encountered or noted at OW4 and OW5.

Based on the borehole results and the previous descriptions of the borrow pit excavation, the aerial extent of waste is assumed to coincide with the cultivated area.

Along the line of north-south cross-section B-B′ (Figure 8), the extent of waste is defined by the three boreholes. The waste encountered at OW5 is assumed to be at the edge of the landfill (and therefore of limited depth), whereas OW2 is assumed to be just south of the landfill edge.

Along the west-east line of cross-section A-A′ (Figure 7), the extent of the waste is less precisely defined. Both OW1 and OW6 are assumed to be located near the west and east edges of the landfill respectively. Based on the descriptions of the previous borrow pit operation, the landfill is assumed to extend to the westward and eastward edges of the cultivated area, as shown on the cross-section.

The maximum depth to which waste was encountered was 13.7 metres at OW4 This is assumed to be the maximum depth of waste across the entire landfill as it also corresponds to the maximum depth of pit excavation at what would have been the centre of the pit.

A leachate well was not installed at OW4 because the water table was found to be 2 metres below the waste. Any leachate generated at this location is expected to migrate vertically to the water table.

4.3 SITE HYDROGEOLOGY

Response test results and analyses are presented in Appendix C, and are summarized in Table 4. Water level measurements and elevations are presented in Appendix B (in table and hydrograph form) and summarized in Table 5.

Hydraulic gradient, groundwater velocity and flux calculations are shown in Appendix D.

4.3.1 General Site Profile

The depth to the water table on-site was found to be relatively deep, on the order of 11 to 15 metres below ground surface. The water table was observed to be near the bottom of the sand unit at OW1 and within the silty fine sand unit in the remaining observation wells. Response tests indicate that the hydraulic conductivity of this silty water table aquifer is on the order of 10-6 m/s.

MONITOR	HYDRAULIC CONDUCTIVITY (m/s)	GEOLOGIC MATERIAL
OW1	6×10^{-6}	Sand to silty fine sand
OW2	2×10^{-5}	Sandy silt
OW4	5×10^{-6}	Sand, some silt
OW5	5×10^{-6}	Silt
OW6	6×10^{-6}	Silty sand to silt
SB1	5×10^{-6}	Sandy silt to silt
SB2	6×10^{-7}	Sandy silt to silt
SB3	6×10^{-6}	Sandy silt to silt
SB4	8×10^{-6}	Sandy silt to silt

TABLE 4
SUMMARY OF
HYDRAULIC CONDUCTIVITIES

MONITOR	RELATIVE WATER LEVEL ELEVATIONS (metres)						
	Jul-30	Aug-20	Aug-28	Sep-10	Sep-11	Oct-03	Nov-15
Groundwater Elevation							
OW1*	--	87.785	87.91	87.91	87.9	87.94	88.02
OW2	--	86.225	86.34	86.32	86.32	86.33	86.27
OW4	--	85.63	85.75	85.73	85.73	85.745	85.72
OW5	--	--	84.96	84.96	84.96	84.99	84.98
OW6	--	--	84.895	84.85	84.85	84.85	84.59
SB1	84.1	84.12	--	84.13	--	84.12	84.13
SB2	82.815	82.795	--	82.845	--	82.865	82.865
SB3	81.145	81.14	--	81.195	--	81.17	81.185
SB4	80.28	80.195	--	80.355	--	80.315	80.315
Surface Water Elevations							
SB1-creek	83.02	83.02	--	83.05	--	83.01	83.13
SB2-creek	81.785	81.79	--	81.855	--	81.825	81.855
SB3-creek	80.665	80.67	--	80.715	--	80.685	80.705
SB4-creek	79.665	79.685	--	79.705	--	79.685	79.665

Water Levels reported as relative to top of well at OW1
(assumed to be at 100.000 metres)

TABLE 5 SUMMARY OF WATER LEVEL ELEVATIONS

The water table aquifer is underlain by a silty clay unit which acts as an aquitard. The saturated thickness of this unconfined aquifer is therefore on the order of 4.0 metres at OW1 and 2.4 metres at OW6.

Relative water levels indicate that flow in the water table aquifer is towards the creek or creek valley (eastwards and northward) as shown in Figure 9. Horizontal gradients observed at the site range from 0.01 to 0.06.

Strong upward gradients exist at the creek (from 0.3 to 0.6) indicating that a considerable amount of groundwater is discharging into the creek. Evidence of upwelling of groundwater into the creek was observed at several locations along the creek bottom during the field investigation.

Groundwater was also observed discharging along a seepage face on the streambank through the summer of the 1990 field investigation (Figure 2). The seepage face occurs where the water table intersects the streambank (Figures 7 and 8).

The silty clay unit just below ground surface serves as an aquitard, slowing the infiltration of water into the ground. During rainfall water was observed to pond quite readily on the field. Although no flow channels were observed on-site, other than a roadside ditch, overland flow was observed to tend towards the creek

The sand unit underlying the silty clay would tend to allow

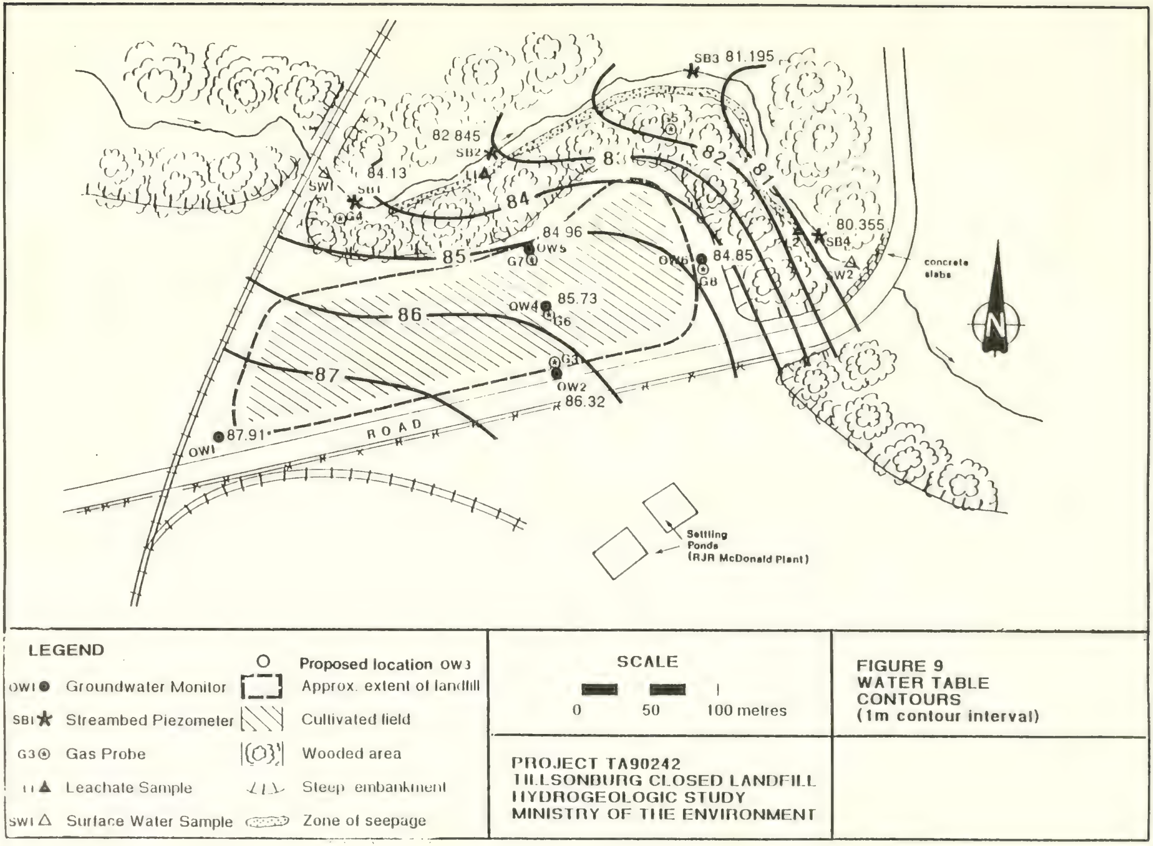


FIGURE 9
WATER TABLE
CONTOURS
(1m contour interval)

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MINISTRY OF THE ENVIRONMENT

infiltrating water to flow through more readily, although it is not observed to be saturated over most of the site. Over most of the site the sand unit has been replaced by the waste. The clayey layers within the waste would tend to slow the downward flow of infiltrating water, and may possibly create localized perched water table conditions. The water table was not observed to be within the waste at the site.

As infiltration into the overlying sand unit is limited by the surficial silts or clays, most of the recharge to the unit is expected to come from horizontal flow from the west and south.

4.3.2 Groundwater Velocity and Flux

Groundwater flow beneath the site is observed to be towards the creek. Groundwater is also observed to discharge along the embankment (as leachate seepage) and into the creek (as upwelling groundwater). Therefore, groundwater velocity and flux calculations can be useful in assessing the potential for transport of landfill impacted groundwater away from the site and towards (and into) the creek. The calculations also give a general indication of the potential for dilution of the impacted groundwater during flow towards and into the creek. However, the calculations can only be interpreted in a general way. Due to the number of "unknowns" in any hydrogeologic setting the numbers derived from such calculations can only be considered to be "ballpark" figures and must be used with care.

Based on the horizontal gradients observed below the site the average linear velocity of the groundwater below the waste is estimated to be in the range of 7 to 40 metres per year.

Based on the observed horizontal gradient and saturated thickness observed at the downgradient edge of the landfill, the volumetric flux from beneath the landfill towards the creek is estimated to be on the order of 11 litres/minute (6 x 106 L/yr).

As a comparison, the volumetric flux estimated flowing onto the site, based on the observed horizontal gradients and saturated thickness at the upgradient edge of the landfill, is estimated to be on the order of 6.5 litres/minute (3.4 x 106 L/yr). Therefore the recharge rate at the site due to infiltration (rainfall) would be on the order of 4.5 litres/minute (2.6 x 106 L/yr), or 0.09 m3/yr/m2. The recharge rate can be considered to be appropriate for the silty clay cover and assuming some evapotranspiration losses due to the corn crop present during the study.

4.4 GROUNDWATER AND SURFACE WATER SAMPLING

Groundwater and surface water samples were obtained from the locations shown on Figure 6. Groundwater samples were taken at locations OW1, OW2, OW4, OW5, OW6, SB1, SB2, SB3 and SB4. Surface water samples were taken at SW1 and SW2. Leachate seepage samples were taken at L1 and L2. The results are shown in chronological order in Tables 6A, 6B, 7, and 8.

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COMPARISON OF ANALYSIS RESULTS:
A&L Laboratories and Canviro Laboratories

PARAMETER	UNIT	STREAM-BED PIEZOMETER				SURFACE WATER			
		SB1 (A&L)	SB2 (A&L)	SB3 (A&L)	SB4 (A&L)	SW1 (A&L)	SW1 Canviro)	SW2 (A&L)	Composite Leachate (A&L)
GENERAL									
pH		8.0	8.1	8.0	8.0	8.2	7.8	8.2	8.1
Conductivity	umho/cm	878	758	800	626	785	607	769	1920
Alkalinity (CaCO)	mg/L	277	218	264	205	321	277	284	659
Hardness (CaCO)	mg/L	353	348	353	285	356	366	364	699
Total Dissolved Solids	mg/L	450	400	430	300	420	410	400	1000
BOD	mg/L					17	<6	18	25
DOC	mg/L	<0.50	<0.05	6.00	6.00	<0.05	2.5	<0.50	1.5
Ammonia	mg/L	0.05	0.06	0.05	0.07	0.06	0.08	0.10	0.50
Phenols	ug/L	3.7	<2	<2	<2	<2	<1	<2	5.5
ANIONS									
Flouride	mg/L	0.26	0.17	0.29	0.30	0.27	0.11	0.28	0.17
Chloride	mg/L	14	15	13	7.6	14	8.64	17	125
Bromide	mg/L						<0.38		
Nitrite	mg/L						<0.06		
Nitrate	mg/L	0.14*	3.7*	0.06*	0.07*	2.8*	4.25	2.5*	0.29*
Phosphate	mg/L						<1.10		
Orthophosphate	mg/L	0.21	0.14	0.15	0.12	0.08		0.15	0.08
Sulphate	mg/L	101	82	93	81	47	38.1	48	27
METALS									
Aluminum	mg/L	4.3	4.1	4.1	3.6	4.3	0.10	4.3	4.8
Boron	mg/L						<0.01		
Barium	mg/L						0.06		
Beryllium	mg/L						<0.005		
Cadmium	mg/L						<0.012		
Calcium	mg/L	113	104	103	84	109	102	109	123
Chromium	mg/L						<0.02		
Cobalt	mg/L						<0.03		
Copper	mg/L	0.02	0.02	0.01	0.02	0.02	<0.01	0.01	0.02
Iron	mg/L	<0.02	<0.02	<0.02	0.17	<0.02	0.13	<0.02	0.42
Lead	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10	<0.01	0.11
Magnesium	mg/L	16.8	21	23	18	20	19.2	22	94
Manganese	mg/L	0.10	0.07	0.03	0.03	0.10	0.11	0.11	0.05
Vanadium	mg/L						<0.01		
Zinc	mg/L	<0.01	0.01	0.01	0.01	0.01	0.25	0.01	0.01
Nickel	mg/L						0.03		
Phosphorus	mg/L						<0.13		
Silver	mg/L						<0.02		
Strontium	mg/L						0.24		
Sodium	mg/L	4.1	5.0	8.3	4.3	5.2	6.44	7.1	121
Potassium	mg/L	1.8	1.4	1.8	1.4	1.7		3.0	31

*Nitrate plus Nitrite
See figure 6 for sample locations
Leachate Sample Composite of Two Seepage Locations

TABLE 6A
SURFACE WATER AND
STREAM-BED PIEZOMETER
SAMPLING (July 30, 1990)

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QUALITY ASSURANCE/
QUALITY CONTROL
SAMPLING

PARAMETER	UNIT	SW1 (Canviro)	SW1 (A&L)	SW1 Duplicate (A&L)	Field Blank (A&L)
GENERAL					
pH		7.8	8.2	8.3	7.1
Conductivity	umho/cm	607	785	734	7.1
Alkalinity (CaCO)	mg/L	277	321	271	2.0
Hardness (CaCO)	mg/L	366	356	348	1.1
Total Dissolved Solids	mg/L	410	420	390	4.2
BOD	mg/L	<6	17	15	13
DOC	mg/L	2.5	<0.05	<0.05	<0.05
Ammonia	mg/L	0.08	0.06	0.08	<0.05
Phenols	ug/L	<1	<2	<2	<2
ANIONS					
Flouride	mg/L	0.11	0.27	0.29	0.10
Chloride	mg/L	8.64	14	14	<0.1
Bromide	mg/L	<0.38			
Nitrite	mg/L	<0.06	2.8*	2.6*	0.05*
Nitrate	mg/L	4.25			
Phosphate	mg/L	<1.10			
Orthophosphate	mg/L		0.08	<0.01	<0.01
Sulphate	mg/L	38.1	47	43	1.0
METALS					
Aluminum	mg/L	0.10	4.3	4.2	<0.03
Boron	mg/L	<0.01			
Barium	mg/L	0.06			
Beryllium	mg/L	<0.005			
Cadmium	mg/L	<0.012			
Calcium	mg/L	102	109	106	0.38
Chromium	mg/L	<0.02			
Cobalt	mg/L	<0.03			
Copper	mg/L	<0.01	0.02	0.01	<0.01
Iron	mg/L	0.13	<0.02	<0.02	<0.02
Lead	mg/L	<0.10	<0.01	<0.01	<0.01
Magnesium	mg/L	19.2	20	20	0.03
Manganese	mg/L	0.11	0.10	0.10	<0.01
Vanadium	mg/L	<0.01			
Zinc	mg/L	0.25	0.01	0.01	<0.01
Nickel	mg/L	0.03			
Phosphorus	mg/L	<0.13			
Silver	mg/L	<0.02			
Strontium	mg/L	0.24			
Sodium	mg/L	6.44	5.2	5.5	0.50
Potassium	mg/L		1.7	1.7	0.50

*Nitrate plus Nitrite
See figure 6 for sample locations
Leachate Sample Composite of Two Seepage Locations

TABLE 6B
SURFACE WATER AND
STREAM-BED PIEZOMETER
SAMPLING (July 30, 1990)

Maximum Acceptable Concentrations Parameters Related to Health	
Parameter	Concentration (mg/L)
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (Free)	0.2
Fluoride	2.4
Lead	0.05
Mercury	0.001
Nitrate (as N)	10.0
Nitrite (as N)	1.0
Selenium	0.01
Silver	0.05
Selenium	0.01
Silver	0.05

Maximum Desirable Concentrations Parameters Related to Aesthetic Quality	
Parameter	Concentration (mg/L)
Chloride	250
Copper	1.0
Iron	0.3
Manganese	0.05
Organic Nitrogen (TKN-Ammonia)	0.15
Phenols	0.002
Sulphate	500
Total Dissolved Solids	500
Total Organic Carbon	5.0
Zinc	5.0

TABLE 6C

MOE ONTARIO DRINKING WATER OBJECTIVES (1983)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	MONITORING WELLS					QA/QC	
		OW1	OW2	OW4	OW5	OW6	OW5 Duplicate	Field Blank
GENERAL								
pH		7.1	6.8	6.9	6.5	7.0	6.4	5.3
Conductivity	umhos/cm	866	1318	3460	3340	2630	3250	658
Alkalinity (CaCO)	mg/L	254	636	1393	1396	1170	1434	3.0
Hardness (CaCO)	mg/L	330	580	950	1060	970	1215	0
Total Dissolved Solids	mg/L	460	735	1870	1740	1260	1760	8
DOC	mg/L	2.6	1.9	59.0	64.7	33.1	65.7	0.4
Ammonia	mg/L	0.02	0.06	34.4	40.9	40.2	42.3	0.17
Phenols	ug/L	<1	28.8	<1	27	39.6	29.2	<1
ANIONS								
Flouride	mg/L	0.13	<0.05	0.12	0.12	0.07	0.12	<0.05
Chloride	mg/L	67.7	8.54	204	175	90.3	173	<0.16
Bromide	mg/L	<1.90	<1.90	<1.90	<1.90	<1.90	<1.90	<0.38
Nitrite	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.06
Nitrate	mg/L	3.38	1.25	<0.90	<0.90	<0.90	<0.90	<0.18
Phosphate	mg/L	<5.50	<5.50	<5.50	<5.50	<5.50	<5.50	<1.10
Sulphate	mg/L	30.1	31.9	<5.90	<5.90	16.1	<5.90	<1.18
METALS								
Aluminum	mg/L	0.07	0.07	0.08	0.10	0.11	0.12	0.05
Boron	mg/L	<0.01	<0.01	1.53	1.52	0.45	1.53	<0.01
Barium	mg/L	0.04	0.06	0.52	0.83	0.21	0.85	<0.01
Beryllium	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/L	<0.012	<0.012	<0.012	<0.012	<0.012	0.018	<0.012
Calcium	mg/L	100	210	220	240	260	220	<0.50
Chromium	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cobalt	mg/L	<0.03	<0.03	0.04	0.05	0.03	0.06	<0.03
Copper	mg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	<0.02	<0.02	20.9	7.00	19.9	7.04	<0.02
Lead	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Magnesium	mg/L	16.1	28.6	69.9	93.7	55.8	92.6	<0.05
Manganese	mg/L	0.02	0.62	0.42	0.18	0.52	0.18	<0.01
Vanadium	mg/L	<0.01	0.01	0.02	0.02	0.02	0.02	<0.01
Zinc	mg/L	<0.01	0.02	0.03	0.03	0.02	0.03	<0.01
Nickel	mg/L	<0.02	0.04	0.15	0.15	0.12	0.18	<0.02
Phosphorus	mg/L	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Silver	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Strontium	mg/L	0.24	0.33	1.42	1.56	0.88	1.57	<0.01
Sodium	mg/L	24.5	9.80	220	130	54.0	125	<0.5
PCB'S								
PCB – 1242	ug/L		<0.015	<0.015	<0.015	<0.015	<0.015	
PCB – 1254	ug/L		<0.032	<0.032	<0.032	<0.032	<0.032	
PCB – 1260	ug/L		<0.032	<0.032	<0.032	<0.032	<0.032	

See Figure 6 for Sample Locations

TABLE 7
MONITORING WELL SAMPLING
(September 11, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	MONITORING WELLS					QA/QC	
		OW1	OW2	OW4	OW5	OW6	OW5 Duplicate	Field Blank
NEUTRAL CHLORINATED EXTRACTABLES								
Hexachlorethane	ug/L		<0.003	<0.003	<0.003	<0.003	<0.003	
1,2,4-Trichlorobenzene	ug/L		<0.002	0.002	<0.002	<0.002	<0.002	
1,2,3-Trichlorobenzene	ug/L		<0.002	<0.002	<0.002	<0.002	<0.002	
Hexachlorobutadiene	ug/L		<0.002	<0.002	<0.002	<0.002	<0.002	
2,4,5-Trichlorotoluene	ug/L		<0.002	<0.002	<0.002	<0.002	<0.002	
1,2,3,5-Tetrachlorobenzene	ug/L		<0.003	<0.003	<0.003	<0.003	<0.003	
1,2,4,5-Tetrachlorobenzene	ug/L		<0.003	<0.003	<0.003	<0.003	<0.003	
Hexachlorocyclopentadiene	ug/L		<0.010	<0.010	<0.010	<0.010	<0.010	
1,2,3,4-Tetrachlorobenzene	ug/L		<0.002	<0.002	<0.002	<0.002	<0.002	
Pentachlorobenzene	ug/L		<0.002	<0.002	<0.002	<0.002	<0.002	
Hexachlorobenzene	ug/L		<0.003	<0.003	<0.003	<0.003	<0.003	
Octachlorostyrene	ug/L		<0.003	<0.003	<0.003	<0.003	<0.003	
BASE NEUTRAL EXTRACTABLES BY "GC/MS"								
Camphene	ug/L		<2.3	0.11	<2.3	<2.3	<2.3	
bis(2-chloroethyl)ether	ug/L		<0.36	0.07	<0.36	<0.36	<0.36	
o-Cresol	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
m-Cresol	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
p-Cresol	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
bis(2-chloroisopropyl)ether	ug/L		<0.09	<0.09	<0.09	<0.09	<0.09	
Phenol	ug/L		0.09	0.47	0.55	0.64	0.13	
Nitrosodi-n-propylamine	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
bis(2-chlorethoxy)methane	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Naphthalene	ug/L		0.59	4.34	0.34	<0.01	<0.01	
2-Chlorophenol	ug/L		<0.03	<0.03	<0.03	<0.03	<0.03	
2,4-Dimethylphenol	ug/L		<0.08	32.8	16.1	6.28	<0.08	
Indole	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2-Methylnaphthalene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
1-Methylnaphthalene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
4-chloro-3-methylphenol	ug/L		<0.02	1.48	<0.02	<0.02	<0.02	
2-chloronaphthalene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
1-chloronaphthelene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,6-dichlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,4-dichlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
Diphenyl ether	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,4,6-trichlorophenol	ug/L		<0.03	<0.03	<0.03	<0.03	<0.03	
Acenaphthylene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,4-dinitrophenol	ug/L		<0.28	<0.28	<0.28	<0.28	<0.28	
2,6-dinitrotoluene	ug/L		<0.57	<0.57	<0.57	<0.57	<0.57	
4-nitrophenol	ug/L		<1.2	<1.2	<1.2	<1.2	<1.2	
Acenaphthlene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,3,5-trichlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,4,5-trichlorophenol	ug/L		<0.04	<0.04	<0.04	<0.04	<0.04	
2,3,4-trichlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,4-dinitrotoluene	ug/L		<0.61	<0.61	<0.61	<0.61	<0.61	
Fluorene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
4-chlorophenyl phenyl ethe	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
4,6-dinitro-o-cresol	ug/L		<9.4	<9.4	<9.4	<9.4	<9.4	
Total Diphenylamine	ug/L		<0.02	0.15	0.06	<0.02	<0.02	
2,3,5,6-tetrachlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
2,3,4,6-tetrachlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	

See Figure 6 for Sample Locations

TABLE 7 (continued)
MONITORING WELL SAMPLING
(September 11, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	MONITORING WELLS					QA/QC	
		OW1	OW2	OW4	OW5	OW6	OW5 Duplicate	Field Blank
BASE NEUTRAL EXTRACTABLES BY "GS/MS"(continued)								
2,3,4,5-tetrachlorophenol	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
4-bromophenyl phenyl ethe	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
Phenanthrene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Anthracene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Pentachlorophenol	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Biphenyl	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
Fluoranthene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Pyrene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Benzybutylphthalate	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
Benzo (a) anthracene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Chrysene	ug/L		<0.11	<0.11	<0.11	<0.11	<0.11	
bis(2-ethylhexyl)phthalate	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Di-n-butylphthalate	ug/L		0.13	0.48	7.10	0.20	0.17	
Benzo (b) fluoranthene	ug/L		<0.02	<0.02	<0.02	<0.02	<0.02	
Benzo (k) fluoranthene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Benzo (a) pyrene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Perylene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
5-Nitroacenaphthene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Indeno(1,2,3-cd)pyrene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Dibenzo(ah)anthracene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
Benzo(ghi)perylene	ug/L		<0.01	<0.01	<0.01	<0.01	<0.01	
VOLATILE ORGANIC COMPOUNDS								
Chloromethane	ug/L		<3.6	<3.6	<3.6	<3.6	<3.6	
Vinyl chloride	ug/L		<5.0	<5.0	<5.0	<5.0	9.6	
Bromomethane	ug/L		<2.0	<2.0	<2.0	<2.0	<2.0	
Chloroethane	ug/L		<1.6	8.5	4.9	13.1	7.8	
Trichlorofluoromethane	ug/L		<3.5	<3.5	<3.5	<3.5	<3.5	
Acrolein	ug/L		<2.2	<2.2	<2.2	<2.2	<2.2	
1,1-Dichloroethylene	ug/L		<1.6	<1.6	<1.6	<1.6	<1.6	
Methylene Chloride	ug/L		<1.8	<1.8	<1.8	<1.8	<1.8	
Acrylonitrile	ug/L		<2.1	<2.1	<2.1	<2.1	<2.1	
trans-1,2-Dichloroethylene	ug/L		<0.7	<0.7	<0.7	<0.7	4.0	
1,1-Dichloroethane	ug/L		<0.5	26.0	37.0	34.1	8.5	
Methyl ethyl ketone	ug/L		<1.1	<1.1	<1.1	<1.1	<1.1	
Chloroform	ug/L		0.9	<0.4	<0.4	<0.4	<0.4	
Bromochloromethane	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	
1,1,1-Trichloroethane	ug/L		<0.5	15.4	1.6	0.8	1.3	
Carbon tetrachloride	ug/L		<0.7	<0.7	<0.7	<0.7	<0.7	
1,2-Dichloroethane	ug/L		<0.3	<0.3	<0.3	<0.3	<0.3	
Benzene	ug/L		<0.4	0.7	8.0	11.0	7.6	
Trichloroethylene	ug/L		<1.9	<1.9	<1.9	<1.9	22.0	
1,2-Dichloropropane	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	
Bromodichloromethane	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	
2-Chloroethylvinyl ether	ug/L		<0.4	<0.4	<0.4	<0.4	<0.4	
trans-1,3-Dichloropropylen	ug/L		<0.3	<0.3	<0.3	<0.3	<0.3	
cis-1,3-Dichloropropylene	ug/L		<0.5	<0.5	<0.5	<0.5	<0.5	
Toluene	ug/L		<0.7	23.4	7.3	1.5	19.0	
1,1,2-Trichloroethane	ug/L		<0.3	<0.3	<0.3	<0.3	<0.3	
Tetrachloroethylene	ug/L		<0.8	0.9	<0.8	<0.8	11.4	
Dibromochloromethane	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	

See Figure 6 for Sample Locations

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TABLE 7 (continued)
MONITORING WELL SAMPLING
(September 11, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
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ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	MONITORING WELLS					QA/QC	
		OW1	OW2	OW4	OW5	OW6	OW5 Duplicate	Field Blank
VOLATILE ORGANIC COMPOUNDS (continued)								
Ethylene dibromide	ug/L		<0.6	<0.6	<0.6	<0.6	<0.6	
Chlorobenzene	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	
m & p Xylene	ug/L		<0.6	<0.6	19.5	40.4	16.4	
Ethyl benzene	ug/L		<2.6	<2.6	15.2	4.5	10.6	
Styrene	ug/L		<0.4	<0.4	<0.4	<0.4	<0.4	
o–Xylene	ug/L		<0.4	<0.4	100.0	23.2	10.2	
Bromoform	ug/L		<0.3	<0.3	<0.3	<0.3	<0.3	
1,1,2,2,-Tetrachloroethane	ug/L		<0.5	<0.5	<0.5	<0.5	<0.5	
1,3–Dichlorobenzene	ug/L		<0.2	<0.2	<0.2	<0.2	<0.2	
1,4–Dichlorobenzene	ug/L		<0.1	<0.1	<0.1	1.1	<0.1	
1,2–Dichlorobenzene	ug/L		<0.4	<0.4	<0.4	<0.4	<0.4	

See Figure 6 for Sample Locations

TABLE 7 (continued)
MONITORING WELL SAMPLING
(September 11, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	STREAM-BED PIEZOMETER	SURFACE WATER		
		SB3	UPSTREAM SW1	DOWNSTREAM SW2	LEACHATE
GENERAL					
pH		7.2	7.6	7.5	7.2
Conductivity	umhos/cm	602	673	718	2010
Alkalinity (CaCO)	mg/L	275	270	280	910
Hardness (CaCO)	mg/L	350	370	755	290
Total Dissolved Solids	mg/L	440	410	10600	1070
BOD	mg/L		<6	<6	
DOC	mg/L	0.8	1.6	2.8	127
Ammonia	mg/L	<0.02	0.04	0.48	33.9
Phenols	ug/L	<1	<1	<1	180
ANIONS					
Flouride	mg/L	0.14	0.10	0.09	0.09
Chloride	mg/L	8.12	12.1	15.0	128
Bromide	mg/L	<0.95	<0.95	<0.95	<0.95
Nitrite	mg/L	<0.30	<0.30	<0.30	<0.30
Nitrate	mg/L	<0.45	4.61	3.68	1.16
Phosphate	mg/L	<2.75	<2.75	<2.75	<2.75
Sulphate	mg/L	59.4	38.9	40.2	<2.90
METALS					
Aluminum	mg/L	<0.05	<0.05	<0.05	<0.05
Boron	mg/L	<0.01	<0.01	<0.01	0.54
Barium	mg/L	0.11	0.06	0.06	0.32
Beryllium	mg/L	<0.005	<0.005	<0.005	<0.005
Cadmium	mg/L	<0.012	<0.012	<0.012	<0.012
Calcium	mg/L	93.1	104	100	180
Chromium	mg/L	<0.02	<0.02	<0.02	<0.02
Cobalt	mg/L	<0.03	<0.03	<0.03	<0.03
Copper	mg/L	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	<0.02	<0.02	<0.02	0.06
Lead	mg/L	<0.10	<0.10	<0.10	<0.10
Magnesium	mg/L	20.5	19.1	20.3	53.8
Manganese	mg/L	0.04	0.15	0.15	0.83
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.02	<0.01	<0.01	0.02
Nickel	mg/L	<0.02	<0.02	<0.02	0.05
Phosphorus	mg/L	<0.13	<0.13	<0.13	<0.13
Silver	mg/L	<0.02	<0.02	<0.02	<0.02
Strontium	mg/L	0.50	0.25	0.26	0.89
Sodium	mg/L	7.26	4.50	6.40	71.8
PCB'S					
PCB – 1242	ug/L	<0.015		<0.015	<0.015
PCB – 1254	ug/L	<0.032		<0.032	<0.032
PCB – 1260	ug/L	<0.032		<0.032	<0.032

See Figure 6 for sample locations

TABLE 8
SURFACE WATER AND STREAM BED
PIEZOMETER SAMPLING, INCLUDING ORGANICS
(October 3, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	STREAM-BED PIEZOMETER	SURFACE WATER		
		SB3	UPSTREAM SW1	DOWNSTREAM SW2	LEACHATE
NEUTRAL CHLORINATED EXTRACTABLES					
Hexachlorethane	ug/L	<0.003		<0.003	<0.003
1,2,4-Trichlorobenzene	ug/L	0.002		0.002	0.006
1,2,3-Trichlorobenzene	ug/L	<0.002		<0.002	<0.002
Hexachlorobutadiene	ug/L	<0.002		<0.002	0.007
2,4,5-Trichlorotoluene	ug/L	<0.002		<0.002	<0.002
1,2,3,5-Tetrachlorobenzene	ug/L	<0.003		<0.003	<0.003
1,2,4,5-Tetrachlorobenzene	ug/L	<0.003		<0.003	<0.003
Hexachlorocyclopentadiene	ug/L	<0.010		<0.010	<0.010
1,2,3,4-Tetrachlorobenzene	ug/L	<0.002		<0.002	<0.002
Pentachlorobenzene	ug/L	<0.002		<0.002	<0.002
Hexachlorobenzene	ug/L	<0.003		<0.003	<0.003
Octachlorostyrene	ug/L	<0.003		<0.003	<0.003
BASE NEUTRAL EXTRACTABLES BY "GC/MS"					
Camphene	ug/L	<2.3		<2.3	<2.3
bis(2-chloroethyl)ether	ug/L	<0.36		<0.36	<0.36
o-Cresol	ug/L	<0.01		<0.01	17.6
m-Cresol	ug/L	<0.01		<0.01	163.3
p-Cresol	ug/L	<0.01		<0.01	43.1
bis(2-chloroisopropyl)ether	ug/L	<0.09		<0.09	<0.09
Phenol	ug/L	<0.06		<0.06	127
Nitrosodi-n-propylamine	ug/L	<0.01		<0.01	<0.01
bis(2-chlorethoxy)methane	ug/L	<0.01		<0.01	<0.01
Naphthalene	ug/L	<0.01		<0.01	<0.01
2-Chlorophenol	ug/L	<0.03		<0.03	<0.03
2,4-Dimethylphenol	ug/L	<0.08		<0.08	276
Indole	ug/L	<0.02		<0.02	<0.02
2-Methylnaphthalene	ug/L	<0.02		<0.02	<0.02
1-Methylnaphthalene	ug/L	<0.02		<0.02	<0.02
4-chloro-3-methylphenol	ug/L	<0.02		<0.02	<0.02
2-chloronaphthalene	ug/L	<0.02		<0.02	<0.02
1-chloronaphthelene	ug/L	<0.02		<0.02	<0.02
2,6-dichlorophenol	ug/L	<0.02		<0.02	<0.02
2,4-dichlorophenol	ug/L	<0.02		<0.02	<0.02
Diphenyl ether	ug/L	<0.02		<0.02	<0.02
2,4,6-trichlorophenol	ug/L	<0.03		<0.03	<0.03
Acenaphthylene	ug/L	<0.02		<0.02	<0.02
2,4-dinitrophenol	ug/L	<0.28		<0.28	<0.28
2,6-dinitrotoluene	ug/L	<0.57		<0.57	<0.57
4-nitrophenol	ug/L	<1.2		<1.2	<1.2
Acenaphthene	ug/L	<0.02		<0.02	<0.02
2,3,5-trichlorophenol	ug/L	<0.02		<0.02	<0.02
2,4,5-trichlorophenol	ug/L	<0.04		<0.04	<0.04
2,3,4-trichlorophenol	ug/L	<0.02		<0.02	<0.02
2,4-dinitrotoluene	ug/L	<0.61		<0.61	<0.61
Fluorene	ug/L	<0.02		<0.02	<0.02
4-chlorophenyl phenyl ethe	ug/L	<0.02		<0.02	<0.02
4,6-dinitro-o-cresol	ug/L	<9.4		<9.4	<9.4
Total Diphenylamine	ug/L	<0.02		<0.02	<0.02
2,3,5,6-tetrachlorophenol	ug/L	<0.02		<0.02	<0.02
2,3,4,6-tetrachlorophenol	ug/L	<0.02		<0.02	<0.02

See Figure 6 for sample locations

TABLE 8 (continued)
SURFACE WATER AND STREAM BED PIEZOMETER SAMPLING, INCLUDING ORGANICS
(October 3, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	STREAM-BED PIEZOMETER	SURFACE WATER		
		SB3	UPSTREAM SW1	DOWNSTREAM SW2	LEACHATE
BASE NEUTRAL EXTRACTABLES BY "GS/MS"(continued)					
2,3,4,5-tetrachlorophenol	ug/L	<0.02		<0.02	<0.02
4-bromophenyl phenyl ethe	ug/L	<0.02		<0.02	<0.02
Phenanthrene	ug/L	<0.01		<0.01	<0.01
Anthracene	ug/L	<0.01		<0.01	<0.01
Pentachlorophenol	ug/L	<0.01		0.07	<0.01
Biphenyl	ug/L	<0.02		<0.02	<0.02
Fluoranthene	ug/L	<0.01		<0.01	<0.01
Pyrene	ug/L	<0.01		<0.01	<0.01
Benzybutylphthalate	ug/L	0.14		0.06	0.11
Benzo (a) anthracene	ug/L	<0.01		<0.01	<0.01
Chrysene	ug/L	<0.11		<0.11	<0.11
bis(2-ethylhexyl)phthalate	ug/L	<0.01		<0.01	<0.01
Di-n-butylphthalate	ug/L	1.34		0.63	0.34
Benzo (b) fluoranthene	ug/L	<0.02		<0.02	<0.02
Benzo (k) fluoranthene	ug/L	<0.01		<0.01	<0.01
Benzo (a) pyrene	ug/L	<0.01		<0.01	<0.01
Perylene	ug/L	<0.01		<0.01	<0.01
5-Nitroacenaphthene	ug/L	<0.01		<0.01	<0.01
Indeno(1,2,3-cd)pyrene	ug/L	<0.01		<0.01	<0.01
Dibenzo(ah)anthracene	ug/L	<0.01		<0.01	<0.01
Benzo(ghi)perylene	ug/L	<0.01		<0.01	<0.01
VOLATILE ORGANIC COMPOUNDS					
Chloromethane	ug/L	<3.6		<3.6	<3.6
Vinyl chloride	ug/L	<5.0		<5.0	<5.0
Bromomethane	ug/L	<2.0		<2.0	<2.0
Chloroethane	ug/L	<1.6		<1.6	<1.6
Trichlorofluoromethane	ug/L	<3.5		<3.5	<3.5
Acrolein	ug/L	<2.2		<2.2	<2.2
1,1-Dichloroethylene	ug/L	<1.6		<1.6	<1.6
Methylene Chloride	ug/L	<1.8		<1.8	<1.8
Acrylonitrile	ug/L	<2.1		<2.1	<2.1
trans-1,2-Dichloroethylene	ug/L	<0.7		<0.7	<0.7
1,1-Dichloroethane	ug/L	<0.5		<0.5	<0.5
Methyl ethyl ketone	ug/L	<1.1		<1.1	200
Chloroform	ug/L	<0.04		<0.04	<0.04
Bromochloromethane	ug/L	<0.2		<0.2	<0.2
1,1,1-Trichloroethane	ug/L	<0.5		<0.5	<0.5
Carbon tetrachloride	ug/L	<0.7		<0.7	<0.7
1,2-Dichloroethane	ug/L	<0.3		<0.3	<0.3
Benzene	ug/L	<0.4		<0.4	0.9
Trichloroethylene	ug/L	<1.9		<1.9	<1.9
1,2-Dichloropropane	ug/L	<0.2		<0.2	<0.2
Bromodichloromethane	ug/L	<0.2		<0.2	<0.2
2-Chloroethylvinyl ether	ug/L	<0.4		<0.4	<0.4
trans-1,3-Dichloropropylen	ug/L	<0.3		<0.3	<0.3
cis-1,3-Dichloropropylene	ug/L	<0.5		<0.5	<0.5
Toluene	ug/L	<0.7		<0.7	33.3
1,1,2-Trichloroethane	ug/L	<0.3		<0.3	<0.3
Tetrachloroethylene	ug/L	<0.8		<0.8	<0.8
Dibromochloromethane	ug/L	<0.2		<0.2	<0.2

See Figure 6 for sample locations

TABLE 8 (continued)
SURFACE WATER AND STREAM BED
PIEZOMETER SAMPLING, INCLUDING ORGANICS
(October 3, 1990)

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGICAL STUDY

ANALYSIS RESULTS FROM CANVIRO LABORATORIES

PARAMETER	UNIT	STREAM-BED PIEZOMETER	SURFACE WATER		
		SB3	UPSTREAM SW1	DOWNSTREAM SW2	LEACHATE
VOLATILE ORGANIC COMPOUNDS (continued)					
Ethylene dibromide	ug/L	<0.6		<0.6	<0.6
Chlorobenzene	ug/L	<0.2		<0.2	<0.2
m & p Xylene	ug/L	<0.6		<0.6	3.0
Ethyl benzene	ug/L	<2.6		<2.6	<1.5
Styrene	ug/L	<0.4		<0.4	<0.4
o–Xylene	ug/L	<0.4		<0.4	2.3
Bromoform	ug/L	<0.3		<0.3	<0.3
1,1,2,2,-Tetrachloroethane	ug/L	<0.5		<0.5	<0.5
1,3–Dichlorobenzene	ug/L	<0.2		<0.2	<0.2
1,4–Dichlorobenzene	ug/L	<0.1		<0.1	<0.1
1,2–Dichlorobenzene	ug/L	<0.4		<0.4	<0.4

See Figure 6 for sample locations

TABLE 8 (continued)
SURFACE WATER AND STREAM BED
PIEZOMETER SAMPLING, INCLUDING ORGANICS
(October 3, 1990)

The sampling program was completed in three stages. An initial sampling round examined the surface and shallow groundwater inorganic chemistry along the creek. The second round examined the organic and inorganic chemistry of the groundwater monitors placed at the landfill. The third round of sampling re-examined some of the surficial inorganic chemistry and the organic chemistry along the creek.

As a check for laboratory accuracy and consistency a triplicate sample was obtained at SW1 and a field blank was prepared during the first sample round. Two of the SW1 samples and the field blank were included in the submission to A & L Laboratories (A & L). The remaining SW1 sample was submitted to Canviro Laboratories (Canviro).

The results of the field blank and triplicate samples indicates that A & L were relatively consistent from sample to sample, but left some doubt as to the accuracy of the results (Table 6A). Also, Canviro offered a more extensive range of parameters in the analysis package. For these reasons Canviro was used for the remainder of the sampling program.

The results will be presented in an order which follows the progression of the landfill impacted groundwater flowing from the landfill into the water table aquifer and towards and into the creek. In this way the chemistry of the most impacted waters can be compared to the chemistry of the ground- and surface waters on site.

4.4.1 Leachate Seep

The leachate seepage was sampled during the first and third sampling rounds. The results of the first and third sample rounds are shown in Tables 6A, 6B and 8. The leachate seepage was found to be the most impacted water sampled at the site and therefore is considered to be the closest approximation to the leachate generated by the landfill as could be obtained in this study.

The first leachate seep sample, which was a composite of locations L1 and L2, was analysed for general inorganic parameters. The results indicate the leachate seep has elevated levels of conductivity, alkalinity, hardness, TDS, BOD, ammonia, phenols, chloride, iron, magnesium and potassium. These levels can be considered to be at the lower end of the typical range of concentrations for landfill generated leachate (Freeze and Cherry).

The sample from location L2, taken during the last sample round, was analysed for both inorganic and organic parameters. The seep was sampled at a point where the leachate pools after seeping from the ground. The leachate was observed to flow directly into the creek from these small pools.

The inorganic results from location L2 indicate elevated levels of conductivity, alkalinity, TDS, DOC, ammonia, phenols and chloride. Levels of barium, calcium, magnesium, manganese and sodium were also elevated. Levels of boron, iron, zinc, nickel and strontium were slightly elevated.

Various organic compounds were detected at low (ppb) levels in the leachate seep sample from location L2. Among those detected were 1,2,4-trichlorobenzene, hexachlorobutadiene, m-, o- and p-cresol, phenol, 2,4-dimethylphenol, methyl ethyl ketone, benzene, toluene, m & p-xylene, and o-xylene.

Several of these organic compounds were found at higher concentrations in the seep sample than directly below the landfill (eg. 2,4-dimethlyphenol at 276 ug/L), however this likely reflects the spatial and temporal variability of trace organic constituents of a domestic landfill (Barker et al, 1986).

4.4.2 Groundwater

The groundwater monitors in the landfilled area; OW1, OW2, OW4, OW5 (duplicated) and OW6, were included in the second sample round. A field blank was also included for QA/QC purposes. The samples were analysed for both inorganic and organic parameters. The results of the second round are shown in Table 7.

Generally the inorganic background water quality is represented by OW1 (the upgradient well). The groundwater sample indicates generally good water quality, within the MOE drinking water objectives (Table 6B). The remaining wells show some impact attributable to the landfill. Elevated parameters include conductivity, alkalinity, hardness, TDS, ammonia, phenols, chloride, barium, calcium, iron, magnesium, manganese, nickel, strontium, and sodium. Wells OW4 and OW5 appear to be impacted to a greater degree than other wells.

Although no PCB's or Neutral Chlorinated Extractables were detected, several other organic parameters were detected at ppb levels. Base Neutral Extractable parameters detected include phenol and napthalene. Volatile organic compounds detected include chloroethane, 1,1-dichloroethylene, 1,1-dichloroethane, 1,1,1-trichloroethane, benzene, trichloroethylene, toluene, tetrachloroethylene, m & p-xylene, ethyl benzene and o-xylene.

Most parameters were detected at very low levels (ie. in the low ppb range). The parameters showing more elevated concentrations at OW4, OW5 and OW6 include chloroethane, 1,1-dichloroehtane, toluene and various xylenes. The highest concentration was noted for o-xylene at 100 ug/L (ppb). These concentrations appear to be on the low end of the range typical range for organic constituents in a domestic landfill (Barker et al, 1986).

The four stream-bed piezometers SB1, SB2, SB3 and SB4 were included in the first sample round. The results of the first sample round are shown in Tables 6A and 6B. The third sampling round included both inorganic and organic parameters at SB3. The results of the third round are shown in Table 8.

Generally the first round of samples indicate that the shallow groundwater along the creek is observed to be similar in quality to both the upgradient water chemistry (OW1) and the surface water chemistry. Groundwater quality along the creek can be of chloride, orthophosphate, sodium and potassium in the surface water samples are observed to rise slightly in the creek as it flows past the site.

During the third sample round both SW1 and SW2 were sampled for inorganic parameters. The SW2 sample was also analysed for organic parameters. The results of the third sample round are shown in Table 8.

The upstream and downstream locations have very similar inorganic sample results. Most parameters fall within drinking water guidelines both upstream and downstream, except manganese which is slightly elevated in both locations. Levels of alkalinity, hardness, TDS, and ammonia are observed to increase from upstream to downstream along the site. Slight increases in conductivity, DOC, chloride, sulphate, magnesium and sodium were also noted.

Organic parameters detected (in the ppb range) at SW2 include 1,2,4-trichlorobenzene and pentachlorophenol.

A comparison of the surface water quality results from the preliminary site inspection by the MOE and the results of this study show little observed change over the 12 year period between sampling.

The chloride level in the stream, a commonly used "indicator" parameter for landfill impact assessments, shows little change between 1978 and 1990. This would suggest that the landfill impact at the stream, although of minor extent, has remained fairly constant throughout this time period.

considered good, most parameters within drinking water guidelines. One exception being manganese, which is slightly elevated above the guidelines. Also, the presence of phenols is noted at SB1.

The third round of samples, at SB3, also indicate that the inorganic results are similar to both the surface waters, as indicated by SW1, and the background groundwater quality, as indicated by OW1.

Organic results at SB3 indicate the presence, at ppb levels, of 1,2,4-trichlorobenzene.

The elevated levels of both inorganic and organic parameters observed in groundwater below the landfill (OW4, OW5 and OW6) are not observed to persist to the stream bed piezometers.

4.4.3 Surface Water

During the first sample round locations SW1 and SW2 were analysed for inorganic parameters.

The surface water chemistry is seen to be similar to that of the shallow groundwater, as indicated by the stream-bed piezometers, and the background water quality, as indicated by OW1. Again, the only parameter exceeding drinking water guidelines is manganese, which is slightly elevated.

Generally the results of the first round indicate that the stream may be slightly impacted by the landfill (Table 6B). The levels

4.5 GAS MONITORING

The gas monitoring results are summarized in Table 9. Generally the results indicate a relatively high rate of methane gas production within the landfill and the possibility of some off-site migration to the south.

At G6 and G7, both placed within the waste encountered in the respective boreholes, levels of methane gas measured were in the 70% (of total volume) range. These monitors indicate a fairly strong rate of methane gas production within the waste (even 11 years after landfilling ceased).

Given the geology of the site some potential exists for gas migration off-site. The waste is deposited in a sand unit most of which lies above the water table, and which may allow gasses to move away from the waste . Over the waste, the clayey cover may tend to prevent vertical gas migration to the atmosphere.

The extent to which the clayey surficial material may prevent gas from flowing upwards to the atmosphere depends on the thickness, continuity and integrity of this material. In the summer some vertical "venting" of gasses is possible through the cover layer. In the winter, when the cover layer would be frozen, the venting of gasses through the cover above the waste would be significantly reduced.

Any build-up of gasses beneath the cover (within the waste) would likely cause the gasses to move through the sand unit away from the waste. The methane gas levels noted at monitors G3 and G8

MONITOR	METHANE GAS LEVEL (% of total volume)	PRESSURE (inches of water)
OW1	0%	--
OW2	0%	--
OW4	0.04%	--
OW5	0.04%	--
OW6	0.02%	--
G3	25%, 30%	1
G4	0%	--
G5	0%	--
G6	70%,70%	1
G7	70% 70%	0.4
G8	70%, 60%, 60%	0.8

TABLE 9
SUMMARY OF GAS MONITORING RESULTS
February 1990

indicate that some movement of gasses within the sand unit away from the landfill is occurring. Given the thickness of the sand unit which is exposed along the embankment to the north and east sides of the landfill, and the relatively short travel distance that the gasses would have from the landfill to the atmosphere along this pathway, it is probable that a significant portion of the volume of gasses produced by the landfill is venting to the atmosphere via this route.

Some concern exist, however, over the possibility of gas migration southward (and westward) towards established industrial operations. The extent of migration would depend on the continuity of both the sand unit and the overlying till unit. Some dilution of the gasses would be expected as the gas would migrate through the sand unit, but the extent of this dilution is unknown.

5.0 DISCUSSION

At the site the water table is observed to be between 11 (at OW1) to 15 (at OW4) metres below ground surface, within the silty sand unit underlying the waste. The silty sand unit is underlain by a clayey layer of unknown extent. The waste has been deposited in an excavated portion of the sand unit, to a maximum observed depth of 13.7 metres below ground surface.

Groundwater flow beneath the site is observed to be northward and eastward, towards the creek. Groundwater recharge to the site due to infiltration is expected to be reduced due to the cultivated surficial silt and clay cover. Horizontal flow is expected to predominate beneath the site as the sand to silty sand layer below the waste is relatively thin (2 to 4 metres thick), and is underlain by a clay layer of lower hydraulic conductivity.

The horizontal gradient at the site is estimated to be in the range of 0.01 to 0.06. The estimated groundwater flux from below the landfill towards the creek is on the order of 11 Litres/min (6 x 106 L/yr). At present the percentage of the this flux discharging as surface seepage is unknown.

The existing upward vertical gradient noted in the stream-bed piezometers indicates considerable groundwater discharge into the creek. During the field investigation, groundwater was observed to upwell directly into the creek. Also, leachate was observed to continuously seep from the embankment along the creek, form into pools, and flow overland into the creek.

Background water quality, as represented by OW1, appears to be good, generally within MOE drinking water guidelines. The water quality of the stream and in the shallow zone beneath the creek is observed to be similar to the background water quality. The similarity in chemistry suggests that groundwater discharge contributes greatly to the creek flow. The groundwater monitors placed below the waste (in the silty sand unit) are observed to be impacted by landfill generated leachate when compared to OW1.

The landfill leachate, as represented by the leachate seep sample and the most impacted groundwater monitors, shows elevated levels of most inorganic parameters. The leachate also shows the presence (at ppb levels) of several organic parameters, including trichloroethylene, perchloroethylene, methyl ethyl ketone, cresols, xylenes and phenols.

The variety and concentration of organic compounds found in the various sampling locations indicates the possibility of the presence of some industrial waste within the landfill, however these parameters are typical of many "domestic" landfills and do not indicate that the leachate emanating from the Tillsonburg closed landfill is worse than at other similar sites. The compounds found may be related to solvents, degreasing agents, gasoline, paints, wood preservatives, textile manufacturing, lubricants and transformer oils, plastics, rubbers, insecticides, herbicides, pesticides, and or the manufacturing of the above.

The concentration and presence of volatile components in the leachate seep is worth noting, given the opportunity for exposure to air (and therefore loss of volatiles) that the leachate had prior to sampling. The concentrations observed in the leachate seepage were higher than those observed directly below the landfill. This may be due to spatial or temporal variations in the landfill output.

Surface water sampling in the creek indicates that although landfill impacted groundwaters and surface waters flow into the creek, little change in surface water quality is observed over the length of the site. Also, little change is observed between the 1978 MOE sampling to the present study. Some organic compounds (at very low concentrations) are found in the creek sample at the point where the creek exits the property. As yet it is unknown if these compounds are present in the creek upstream of the landfill.

The limited impact the landfill is observed to have on the creek may be attributed to several explanations. Although the majority of the landfill impacted water flows towards the creek, the impact is likely diluted down to non-detect levels for most parameters. The dilution is probably a result of the high volume of water flowing along and into the creek from the surrounding area.

The potential for landfill impact on local water supplies is considered minimal. The majority of the private water taking activities with 1 km of the landfill occur upgradient (south) of the site. Therefore, those wells located south of the site (along Highway No. 3), are not at risk due to the presence of the landfill. the closest downgradient wells, the Fairs' wells, are located across the creek from the landfill. As noted previously, most of the groundwater flow beneath the landfill seems to discharge to the creek. Also, the landfill impact is found to be diluted substantially at the creek. Therefore the Fairs' wells are not considered to be at risk due to the landfill. In order to confirm this, the Fairs' drinking water supply well(s) should be included in the future monitoring program for the landfill. The other wells in the area are located further from the landfill, and therefore not considered to be at risk due to the landfill.

The presence of small pools of leachate seepage at the base of the embankment is of some concern. Steps should be taken to isolate the leachate seepage and pool area from public access, perhaps with the use of a perimeter fence and warning signs.

At present there are no structures (buildings) on-site, and therefore no existing landfill gas hazard on-site. As per MOE guidelines, no construction (of buildings etc.) at the landfill site should be allowed. As yet the extent of off-site migration of landfill generated gas is unknown. In order to ensure the safety of present structures and determine an appropriate (if any) "safety" set-back required at the landfill, further study is required.

6.0 CONCLUSIONS

Based on the results of the drilling and sampling programs, the following conclusions can be made:

1) The site is characterized by a surficial layer of clay and/or silt, underlain by a clean sand unit, a silty sand unit and a clayey unit at depth. A portion of the sand unit has been extracted for use off-site, and waste has been placed in the resulting excavation.

2) The waste was encountered to a maximum depth of 13.7 metres below ground surface. The waste appears to be limited to the area of the cultivated field. The waste encountered during drilling appeared to be of domestic origin, although some chemical evidence of the possible presence of industrial waste was found in the groundwater samples.

3) The water table is observed to be generally within the silty sand unit below the waste, at a depth on the order of 11 to 15 metres below ground surface.

4) Groundwater flow direction appears to be towards the creek which borders the landfill to the north and east. Landfill generated leachate is observed to seep from the embankment along the creek and flow into the creek. Groundwater is observed to upwell or discharge into the creek.

5) Background water quality, as indicated by the upgradient well OW1, appears to be good. All parameters are within MOE drinking water quality guidelines.

6) The groundwater directly below the landfill is impacted by the landfill. Most inorganic parameters analysed for were found to be elevated above background water quality and MOE drinking water guidelines. Several organic compounds which may be attributable to domestic or industrial waste were found at ppb levels in the landfill impacted groundwaters.

7) Landfill leachate is observed to seep from the embankment between the landfilled area and the creek. The leachate is observed to pool in flat areas along the creek. The leachate is found to contain elevated levels of most inorganic parameters tested for. The leachate also is found to contain several organic compounds, including cresols, phenol, methyl ethyl ketone, benzene, toluene and xylenes. These parameters can be considered typical of leachate derived from domestic landfills.

8) Little change in inorganic water chemistry is observed from the MOE samples taken in 1978 and 1980 to the samples obtain in this study. The chloride concentration, a commonly used indicator parameter, is observed to remain at a relatively constant level from

1978 to the present.

9. Surface water quality in the creek is very similar to the background groundwater quality. Over the length of the site little change is noted in the water quality of the stream. Some organic parameters were detected in the water at the downstream edge of the site, as yet it is unknown if these parameters exist in the water upstream of the site. The landfill site appears to have limited impact on the stream.

10) Methane gas was detected within and to the south and east of the waste. No structures are present on-site, and therefore there is no specific methane gas hazard on-site at the present time. No structures should be allowed to be constructed on-site in the future. Some potential exists for gas migration off-site southward towards an existing plant site.

7.0 RECOMMENDATIONS

Based on the study, the following recommendations can be made:

1) The potential for landfill generated gasses (methane) to migrate southward and westward towards existing (off-site) structures should be investigated. the study should determine the presence or absence of the surficial till layer in this area through soil sampling. The study should also include the installation of several gas probes both adjacent to the landfill (but not within the waste) and further from the site. A short-term monitoring program should be designed to establish methane gas concentrations at each probe site in both summer and winter conditions. The study should draw conclusions regarding the potential for and/or extent of gas migration and make recommendations for safety measures or set backs if necessary.

2) In order to avoid direct contact with the leachate, some action should be taken to restrict public access to the existing landfill seepage which collects along the creek (perhaps with a perimeter fence and warning signs).

3) In order to assess the yearly fluctuation in both leachate production and the landfill impact on the creek and the local shallow aquifer, a short-term (1 or

2 year) monitoring program should be initiated. The monitoring program should include the sampling of background groundwater quality (at OW1), the most impacted well (OW4 or OW5), the leachate seepage (composite of L1 and L2) and both upstream and downstream locations. The Fairs′ private drinking water supply well should also be sampled. The parameters analysed for should be consistent with the present study and include: pH, Conductivity, TDS, BOD (surface waters), DOC, Ammonia, Phenols, Anions and Metals (including Boron). These samples should be taken in spring and fall, at times of high and low baseflow conditions respectively. Water level monitoring at all monitoring wells and streambed piezometers should also be included. In this way a more complete picture of the landfill impact on the creek and the local shallow aquifer may be assembled, and further monitoring recommendations (if any) can be made.

APPENDIX A

MOE Sampling Results

Ministry of the Environment

Ontario

MAY 2 0 1980

LABORATOR...

Municipality: TOWN OF TILLSONBURG, OXFORD CTY
Source: STREAM
Program: IML
Date sampled: MAY 1/80 by: S. CHECK
Date analysed: Date reported: MAY 2 0 1980

Report to: S. CHECK Tel:
Address: LONDON REGIONAL OFFICE

C	
Bi	
Ba	

LAB NUMBER	SENDER'S NUMBER	SAMPLING POINT LOCATIONS AND TIME	NATURE OF SAMPLE, DANGEROUS CONSTITUENTS, PRESERVATIVES USED, COMPOSITING DATA, ETC.	✓CHECK BELOW IF CHLORINE PRESENT
LW 585	#1	TILLSONBURG LANDFILL SITE POLLUTION SURVEY (DOWNSTREAM FROM SITE)		

SEE DIRECTIONS OVER

RECEIVED
MAY 16 1980
LONDON REGIONAL LABORATORY

LAB. NUMBER	CALCIUM AS CA	MAGNESIUM AS Mg	CALCULATED HARDNESS	ALKALINITY AS CaCO₃	CHLORIDE AS Cl	pH	IRON as Fe	SODIUM AS Na	POTASSIUM AS K	Sulphate as SO₄	COD
LW 585	101.	21.1	341	290	18.5	8.05	0.08	7.2	2.30	14.0	22

	NITROGEN AS N				PHOSPHORUS AS P		PHENOLS	CARBON		
	Free Ammonia	Total Kjeldahl	Nitrite	Nitrate	TOTAL	DISS. REACTIVE	IN PPB	TOTAL	INORG	ORG
LW 585	0.130	0.56	0.051	5.95	0.016	0.001	8.0	83.0	66.0	17.0

FOR [illegible] ONLY

Ministry of the Environment
Ontario

LABORATORIES

Sample Submission Form

Municipality TOWN OF TILLSONBURG, OXFORD CTY
Source STREAM
Program: PAL
Date sampled AUG 13/80 by S. CHECK
Date analysed 9/6/80 Date reported

Report to: S. CHECK Tel:
Address: LONDON REGIONAL OFFICE

C	I
Br	
Bo	

LAB NUMBER	SENDER'S NUMBER	SAMPLING POINT LOCATIONS AND TIME	NATURE OF SAMPLE DANGEROUS CONSTITUENTS, PRESERVATIVES USED, COMPOSITING DATA, ETC.	✓CHECK BELOW IF CHLORINE PRESENT
H21 53	#1	TILLSONBURG LANDFILL SITE POLLUTION SURVEY (DOWNSTREAM FROM SITE)		

SEE DIRECTIONS OVER

LAB NUMBER	Zn	Cu	Ni	Pb	Cd	Cr	Mo	Ti	V.
H21 53	<.01	<.01	<.02	<.03	<.005	<.02	<.02	<0.45	<.02
	Mn	Ba	Hg	Li	Se	As	CN		
	.19	.09	<.005	<.005	<0.001	<0.001	<.01		

FOR LAB USE ONLY

MINISTRY OF THE ENVIRONMENT
ONTARIO
SEP 11 1980
REGIONAL OFFICE
LONDON

SHEET

Ministry of the
Environment

TABLE I
SUMMARY OF CHEMICAL ANALYSES OF WATER

All analyses except pH reported in mg/l unless otherwise indicated

Southwestern Region
Technical Support Section
985 Adelaide St. South, London N6

OXFORD

Township(s): SOUTHWEST OXFORD

Date compiled: Nov./78 Compiler: P. Rasmussen

Owner or Source	Location: Township	Location: Lot	Location: Concession	Date Sampled D/M/Y	Hydrogen Sulphide as H_2S	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Iron as Fe	pH at lab	Apparent Colour, in Hazen Units	Turbidity, in Formazin Units	Conductance, in micromhos/cm-25°C	Fluoride as F	Chloride as Cl	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Nitrogen as N: Free Ammonia	Nitrogen as N: Total Kjeldahl	Nitrogen as N: Nitrite	Nitrogen as N: Nitrate	Phosphorus as P: Dissolved Reactive	Phosphorus as P: Total
Stream, upstream from the landfill		8	XII	[illegible]		345	262	0.10	7.93			650		12.0	52	105	20.0	4.2	1.50	0.095	0.130	0.018	1	0.009	0.013
groundwater seep, from [illegible] stream valley		8	XII	[illegible]		752	682	3.75	7.26			1240		27.5	32.0	225	46.0	10.5	0.60	0.015	0.345	0.019	2.19	0.003	0.021
Stream, downstream from the landfill		8	XII	[illegible]		364	294	0.76	7.82			679		17.0	51	109	22.0	2.6	1.05	0.285	0.570	0.083	4.15	0.001	0.014

[illegible] figure, N.D. – Not detected, < – Refers to less than, 1mg/l = 1ppm = 1lb/100,000 Imp. gal ; 1µg/l = 1ppb.

[illegible]

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vironment

TABLE I Cont'd
SUMMARY OF CHEMICAL ANALYSES OF WATER

All analyses except pH reported in mg/l unless otherwise indicated

Southeastern Region
Technical Support Section
985 Adelaide St. South, L

Owner(s): [illegible] Township(s): Southwest Oxford Date compiled: Nov 1/78 Compiler: [illegible]

Owner or Source	Location: Lot	Location: Concession	Location: Township	Date Sampled d/m/y	Biochemical Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)	Carbon: Inorganic	Carbon: Organic	Carbon: Total	Petroleum Hydrocarbons	Tannins and Lignins	Reactive Silicate as Si	Total Dissolved Solids	Selenium as Se	Arsenic as As	Barium as Ba	Cadmium as Cd	Chromium as Cr	Copper as Cu	Cyanide as CN	Lead as Pb	Manganese as Mn	Nickel as Ni	Zinc as Zn	So TOTAL
[illegible] stream [illegible] the [illegible]	8	XII		11/10/11	0.3	13																			420
groundwater [illegible] from [illegible] of [illegible] valley	8	XII		11/10/11	195	329																			1326
[illegible] downstream [illegible] the [illegible]	8	XII		11/10/11	18	23																			442

* shown in Figure ; N.D. = Not Detected ; P = Present ; < Refers to less than ; 1 mg/l 1 ppm = 1lb/100 000 gal ; 1 ug/l = 1 ppb

APPENDIX B

Borehole Logs

	RELATIVE * GROUND SURFACE ELEVATION (metres)	RELATIVE * TOP OF WELL ELEVATION (metres)	TOTAL DEPTH (MBGS)	SCREENED INTERVAL (MBGS)
OW1	99.135	100.000	15.5	11.8 – 14.9
OW2	100.350	101.190	17.1	15.0 – 16.5
OW4	100.475	101.370	18.3	16.8 – 18.3
OW5	100.420	101.310	18.9	16.8 – 18.3
OW6	97.345	98.070	15.5	12.8 – 14.3
SB1	82.870**	84.250	3.23	3.09 – 3.23
SB2	81.675**	82.865	3.075	2.935 – 3.075
SB3	80.530**	81.815	3.08	2.94 – 3.08
SB4	79.515**	80.765	3.08	2.94 – 3.08

* Relative to OW1 – Top of Well
**Stream Bed Elevation

TABLE B1 MONITORING WELL
INSTALLATION SUMMARY

Terraqua Investigations Ltd.

BOREHOLE NO. OW1

PROJECT: TILLSONBURG LANDFILL, TA90242

CLIENT: MINISTRY OF THE ENVIRONMENT

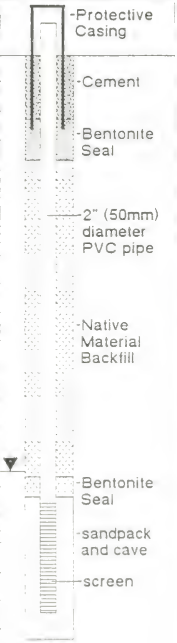
BOREHOLE TYPE: Hollow Stem Auger

DATE: August 16, 1990.

RELATIVE ELEVATIONS:
Ground Surface: 99.135 metres
Top of Well: 100.000 metres

DEPTH feet metres)	DESCRIPTION	SAMPLES		
		NO	TYPE	BLOW COUNT
		AS: auger sample SS: split spoon		
0	TOPSOIL		AS	
	SILT, some clay, tan, moist.	1	SS	4,5,8
10 (3.05)	SILTY fine SAND, finely layered, with interlayers of silt, brown, dry.	2	SS	N/A
	SAND, fine, clean, tan, dry.	3	SS	4,8,9
20 (6.10)	- finely layered, dry.	4	SS	N/A
	- fine dark silty layers, compact, moist.	5	SS	15,23,38
30 (9.14)	- as above, with a reddish silty layer, wet at 31'.	6	SS	20,39,45
	- grey, layered, saturated.	7	SS	21,33,23
40 (12.19)	- as above.	8	SS	19,21,15
		9	SS	N/A
	SILTY fine SAND, grey, layers of reddish brown silt, saturated.			
50 (15.24)		10	SS	9,24,29
	CLAY, some silt, with silt and clay layers, grey, moist			
	END OF BOREHOLE			
60 (18.29)				

GROUND WATER MONITORS



▼ static water level Nov. 15/90

Terraqua Investigations Ltd.

BOREHOLE NO. OW2

PROJECT: TILLSONBURG LANDFILL, TA90242

CLIENT: MINISTRY OF THE ENVIRONMENT

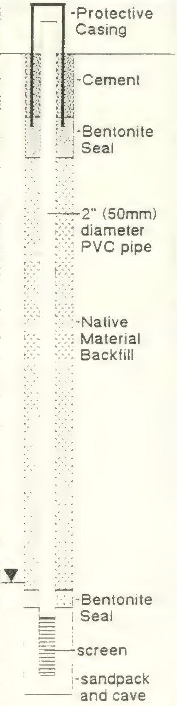
BOREHOLE TYPE: Hollow Stem Auger

DATE: August 17, 1990.

RELATIVE ELEVATIONS:
Ground Surface: 100.350 metres
Top of Well: 101.190 metres

DEPTH feet (metres)	DESCRIPTION	SAMPLES NO	SAMPLES TYPE	SAMPLES BLOW COUNT
		AS: auger sample SS: split spoon		
0				
	TOPSOIL	1	AS	
	SILTY SANDY CLAYEY FILL, brown, moist.	2	SS	N/A
10 (3.05)	- some small stones, light brown, dry to slightly moist.	3	SS	N/A
	SAND, fine, clean, tan, dry.	4	SS	20,24,29
20 (6.10)	- finely layered ,some dark layers, wet.	5	SS	20,29,10
	SILTY fine SAND, with clay layer at 20', light brown, moist.			
	- layer of fine tan sand, dry.	6	SS	30,33,34
30 (9.14)	SILT, some clay, layered, wet.	7	SS	19,34,36
	SAND, fine, clean, tan, dry.			
	- as above.	8	SS	23,93
40 (12.19)	- very fine, layered, trace silt in some layers.	9	SS	29,55,53
	- trace silt, very wet.	10	SS	N/A
50 (15.24)	fine SANDY SILT, layered, light brown, saturated.	11	SS	12,15,21
	- trace sand, saturated.	12	SS	20 for 2'
	END OF BOREHOLE			
60 (18.29)				

GROUND WATER MONITORS



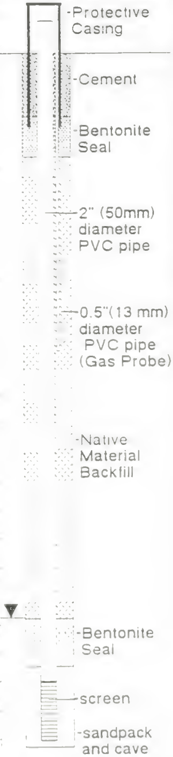
▼ static water level Nov. 15/90

Terraqua Investigations Ltd.	BOREHOLE NO. OW4
PROJECT: TILLSONBURG LANDFILL, TA90242	DATE: August 17, 1990.
CLIENT: MINISTRY OF THE ENVIRONMENT	RELATIVE ELEVATIONS:
BOREHOLE TYPE: Hollow Stem Auger	Ground Surface: 100.475 metres Top of Well: 101.370 metres

AS: auger sample
SS: split spoon

DEPTH feet (metres)	DESCRIPTION	SAMPLES NO	SAMPLES TYPE	SAMPLES BLOW COUNT
0	TOPSOIL	1	AS	
	WASTE, evidence of domestic refuse, interlayered with silty sandy clayey fill, dry to moist.		AS	
10 (3.05)	- domestic refuse (plastic, cardboard, cloth, porcelein, metal cans, etc.), and fill.		AS	
	- as above.		SS	66 for 1.5'
20 (6.10)	- as above.		SS	7,6,5
	- as above, sandy fill.		SS	12,15,10
30 (9.14)	- as above.		SS	10,12,6
	- some glass.		SS	11,9,12
40 (12.19)	- refuse mixed with clayey silty gravelly fill, wet silty clay layers.		SS	46 for 2'
	SAND, fine, some silt, layered (dark bands), grey.	2	SS	35,49,47
50 (15.24)	- grey, wet, with silty clay layer.	3	SS	32 for 2'
	- saturated.	4	SS	7,8,9
	-as above.	5	SS	21 for 2'
60 (18.29)	END OF BOREHOLE			

GROUND WATER MONITORS



-Protective Casing
-Cement
-Bentonite Seal
-2" (50mm) diameter PVC pipe
-0.5"(13 mm) diameter PVC pipe (Gas Probe)
-Native Material Backfill
-Bentonite Seal
-screen
-sandpack and cave

▼ static water level Nov. 15/90

Terraqua Investigations Ltd.

BOREHOLE NO. OW5

PROJECT: TILLSONBURG LANDFILL, TA90242

CLIENT: MINISTRY OF THE ENVIRONMENT

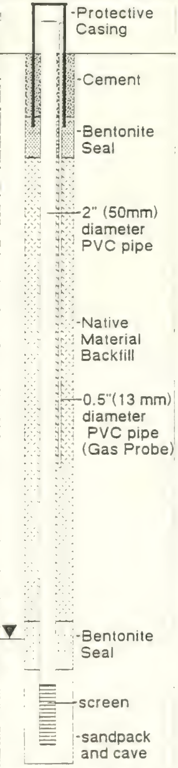
BOREHOLE TYPE: Hollow Stem Auger

DATE: August 20, 1990.

RELATIVE ELEVATIONS:
Ground Surface: 100.420 metres
Top of Well: 101.310 metres

DEPTH feet (metres)	DESCRIPTION	SAMPLES NO	SAMPLES TYPE	SAMPLES BLOW COUNT
		AS: auger sample SS: split spoon		
0				
	TOPSOIL	1	AS	
	- grey-brown to black clayey silty soil.	2	SS	N/A
10 (3.05)	WASTE, evidence of domestic refuse, interlayered with silty sandy clayey fill, dry to moist.		AS	
	- domestic refuse (plastic, cardboard, cloth, porcelein, metal cans, etc.), and fill.		AS	
20 (6.10)	- as above.		AS	
	SAND, fine, layered (with dark bands), some silt, grey to tan, compact, dry.	3	SS	135 for 2'
30 (9.14)	- red clay layer.	4	SS	N/A
	- as above, finely layered.	5	SS	190 for 2"
40 (12.19)	- as above, dry.	6	SS	121 for 2"
	- wet, silt content increasing.	7	SS	84 for 2'
50 (15.24)	SILT, some very fine sand, saturated.	8	SS	39 for 2'
	- grey, no sand present, saturated.	9	SS	15 for 2'
60 (18.29)	- as above.	10	SS	20 for 2'
	END OF BOREHOLE			

GROUND WATER MONITORS


-Protective Casing
-Cement
-Bentonite Seal
-2" (50mm) diameter PVC pipe
-Native Material Backfill
-0.5"(13 mm) diameter PVC pipe (Gas Probe)
-Bentonite Seal
-screen
-sandpack and cave

▼ static water level Nov. 15/90

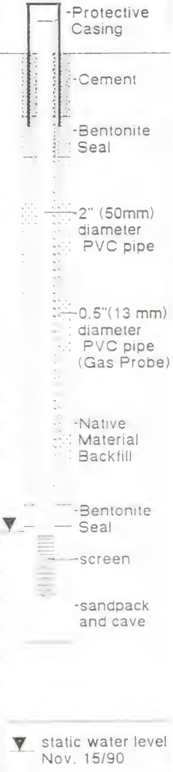
Terraqua Investigations Ltd. BOREHOLE NO. OW6

PROJECT: TILLSONBURG LANDFILL, TA90242
CLIENT: MINISTRY OF THE ENVIRONMENT
BOREHOLE TYPE: Hollow Stem Auger

DATE: August 21, 1990.
RELATIVE ELEVATIONS:
Ground Surface: 97.345 metres
Top of Well: 98.070 metres

DEPTH feet (metres)	DESCRIPTION	SAMPLES NO	SAMPLES TYPE	SAMPLES BLOW COUNT
		AS: auger sample SS: split spoon		
0	TOPSOIL	1	AS	
	SILTY CLAY, some gravel, reddish-brown, mottled grey, dry to moist.	2	SS	N/A
10 (3.05)	SAND, fine, layered (with dark bands), trace silt, dry.	3	SS	N/A
	SAND, SILT and CLAY layers, sand tan, silt and clay reddish brown, dry.	4	SS	N/A
20 (6.10)	- massive brown silt layer over finely layered fine sand, moist.	5	SS	N/A
	- layered brown silt, dry to moist.	6	SS	N/A
30 (9.14)	SILTY fine SAND, tan to grey with dark fine layers, cross-bedding, moist.	7	SS	N/A
	- grey with dark or reddish silt layers.	8	SS	N/A
40 (12.19)	- cross-bedding, saturated.	9	SS	N/A
	SILT, layered, grey-brown, saturated.	10	SS	N/A
50 (15.24)	CLAY, massive, brown to grey, wet.	11	SS	N/A
	END OF BOREHOLE			
60 (18.29)				

GROUND WATER MONITORS


-Protective Casing
-Cement
-Bentonite Seal
-2" (50mm) diameter PVC pipe
-0.5"(13 mm) diameter PVC pipe (Gas Probe)
-Native Material Backfill
-Bentonite Seal
-screen
-sandpack and cave
▼ static water level Nov. 15/90

APPENDIX C

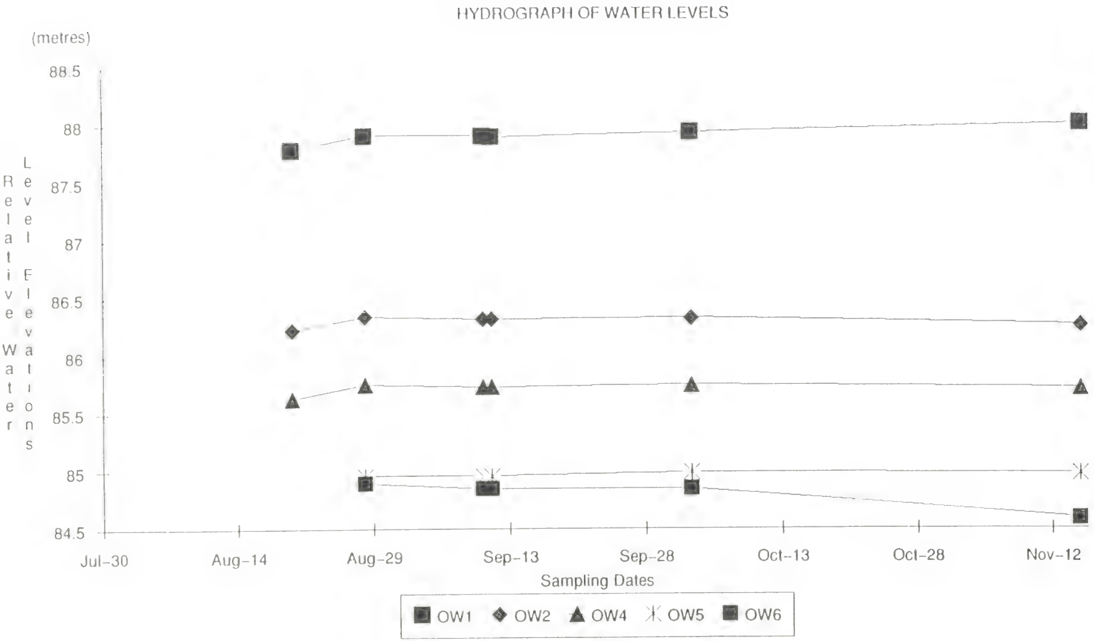
Water Levels

MONITOR	RELATIVE TOP OF WELL ELEVATION	DEPTH TO WATER (metres)						
		Jul-30	Aug-20	Aug-28	Sep-10	Sep-11	Oct-03	Nov-15
OW1*	100.000	--	12.215	12.090	12.090	12.100	12.060	11.980
OW2	101.190	--	14.965	14.850	14.870	14.870	14.860	14.920
OW4	101.370	--	15.740	15.620	15.640	15.640	15.625	15.650
OW5	101.310	--	--	16.350	16.350	16.350	16.320	16.330
OW6	98.070	--	--	13.175	13.220	13.220	13.220	13.480
SB1	84.250	0.150	0.130	--	0.120	--	0.130	0.120
SB2	82.865	0.050	0.070	--	0.020	--	0.000	0.000
SB3	81.815	0.670	0.675	--	0.620	--	0.645	0.630
SB4	80.765	0.485	0.570	--	0.410	--	0.450	0.450
SB1-creek**	84.250	1.230	1.230	--	1.200	--	1.240	1.120
SB2-creek	82.865	1.080	1.075	--	1.010	--	1.040	1.010
SB3-creek	81.815	1.150	1.145	--	1.100	--	1.130	1.110
SB4-creek	80.765	1.100	1.080	--	1.060	--	1.080	1.100

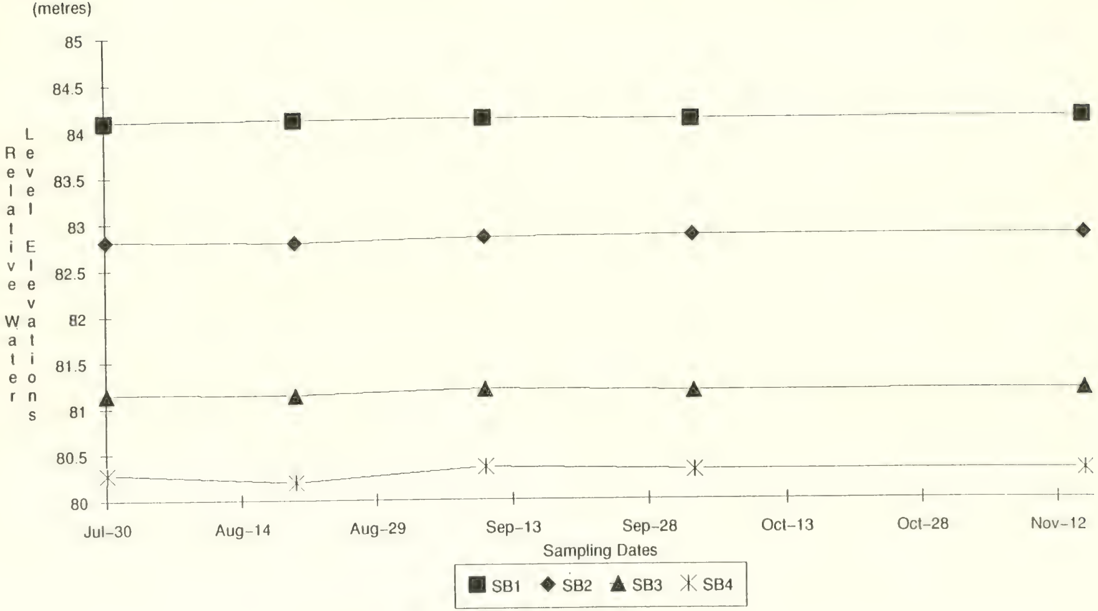
* – Relative top of well elevation assumed

**–creek level measured from top of well

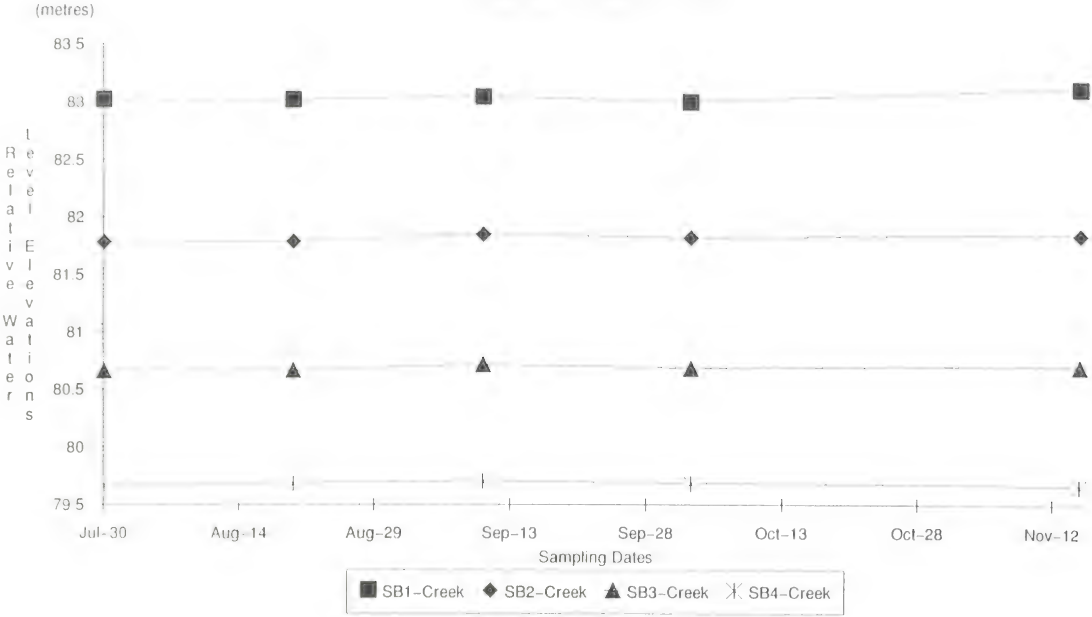
TABLE C1 SUMMARY OF WATER LEVEL MEASUREMENTS


HYDROGRAPH OF WATER LEVELS
(metres)
Relative Water Level Elevations
88.5
88
87.5
87
86.5
86
85.5
85
84.5
Jul-30
Aug-14
Aug-29
Sep-13
Sep-28
Oct-13
Oct-28
Nov-12
Sampling Dates
OW1
OW2
OW4
OW5
OW6

HYDROGRAPH OF WATER LEVELS



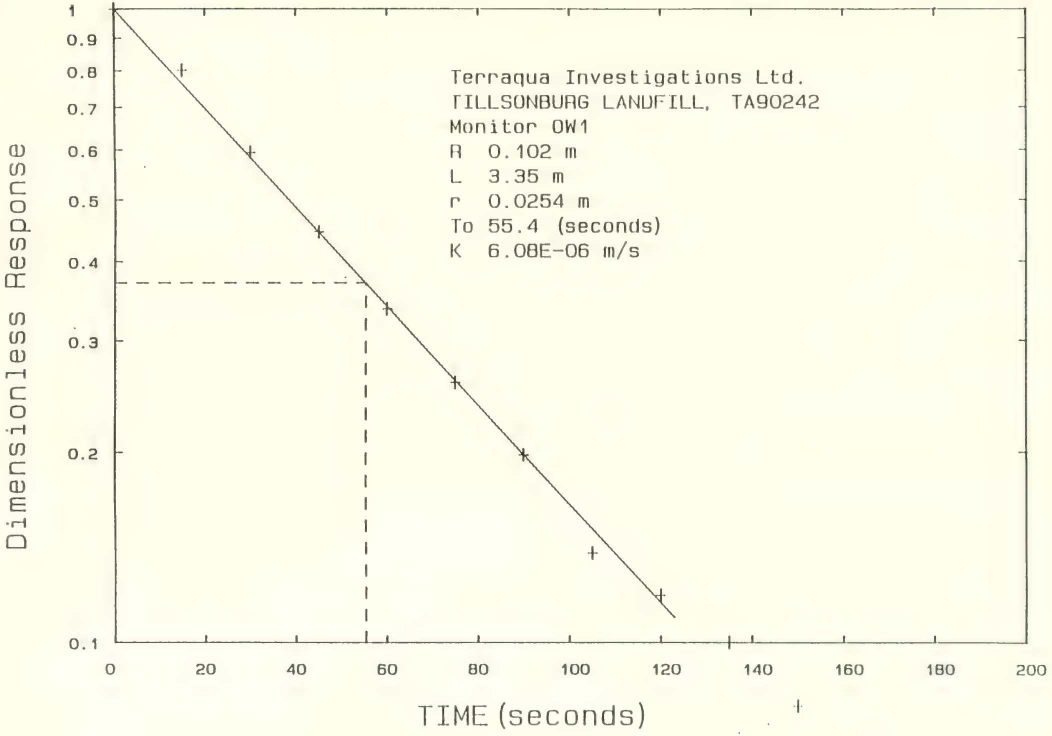
HYDROGRAPH OF WATER LEVELS



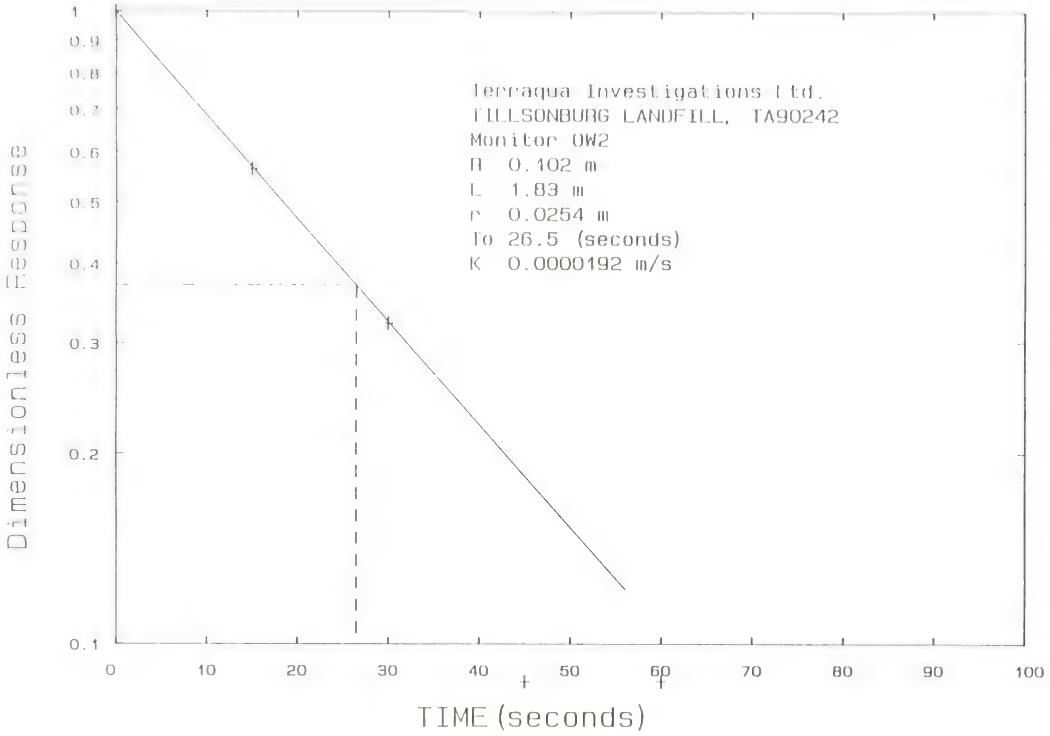
APPENDIX D

Response Tests

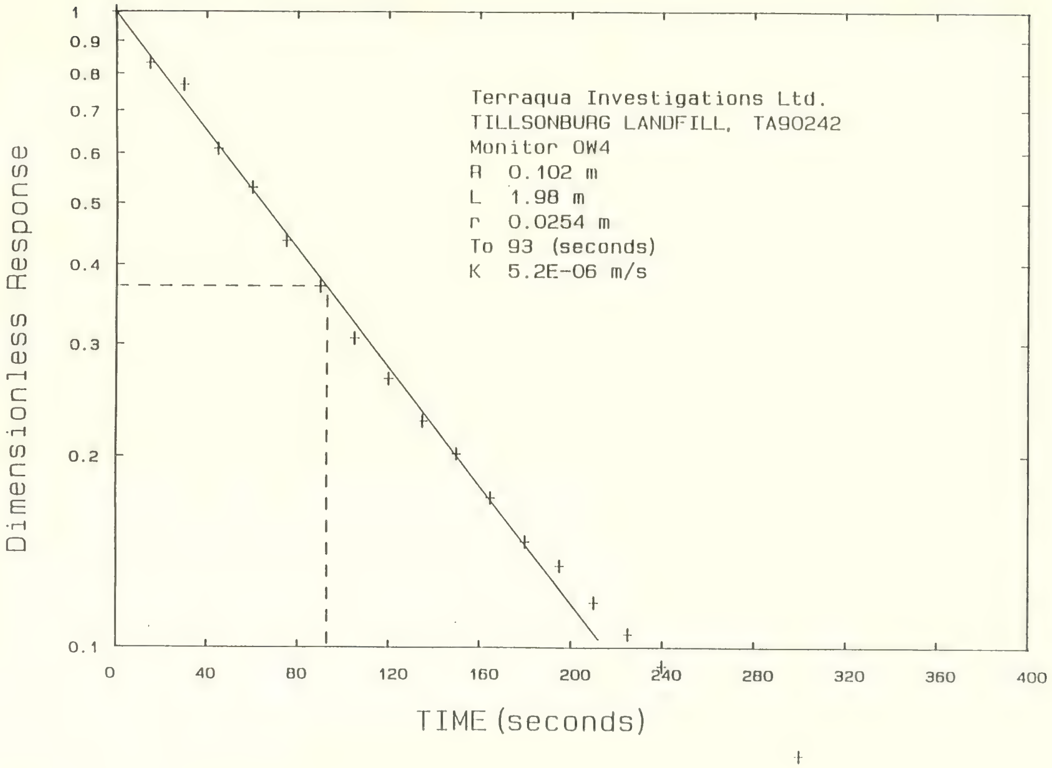
RESPONSE TEST ANALYSIS



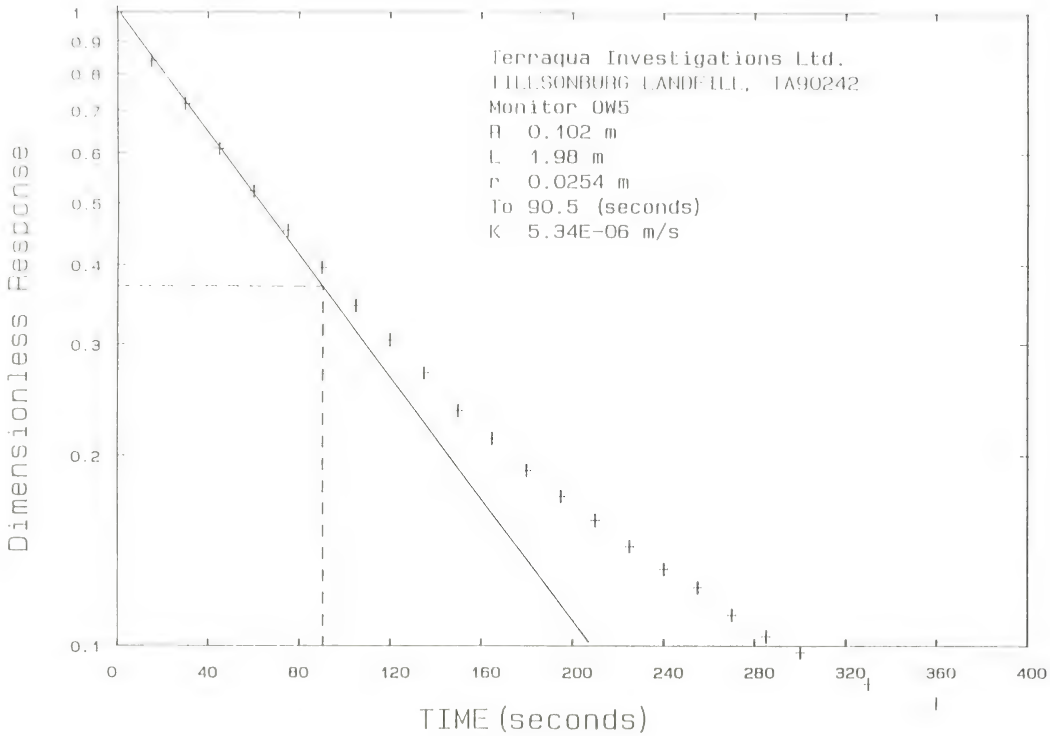
RESPONSE TEST ANALYSIS



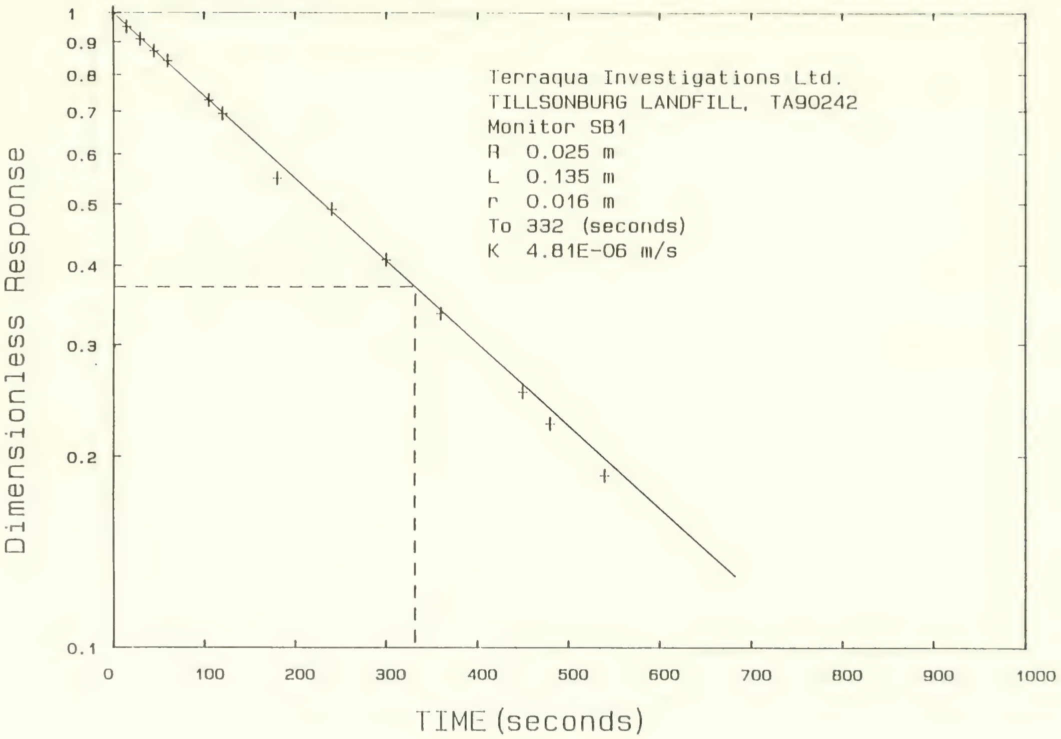
RESPONSE TEST ANALYSIS



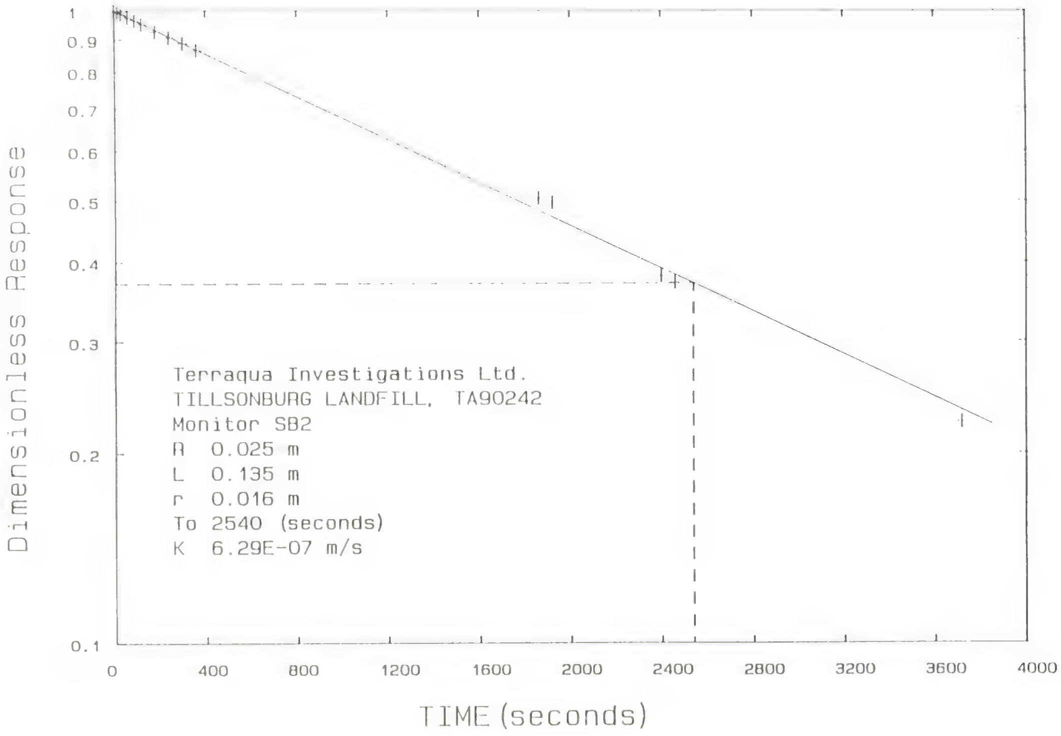
RESPONSE TEST ANALYSIS



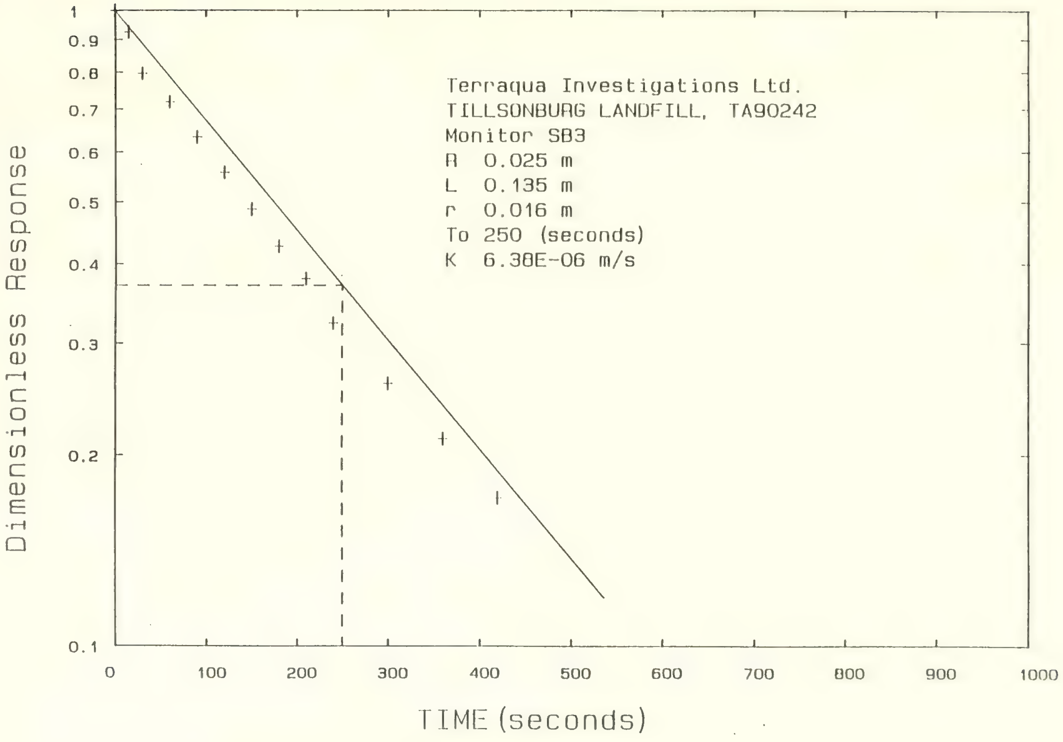
RESPONSE TEST ANALYSIS



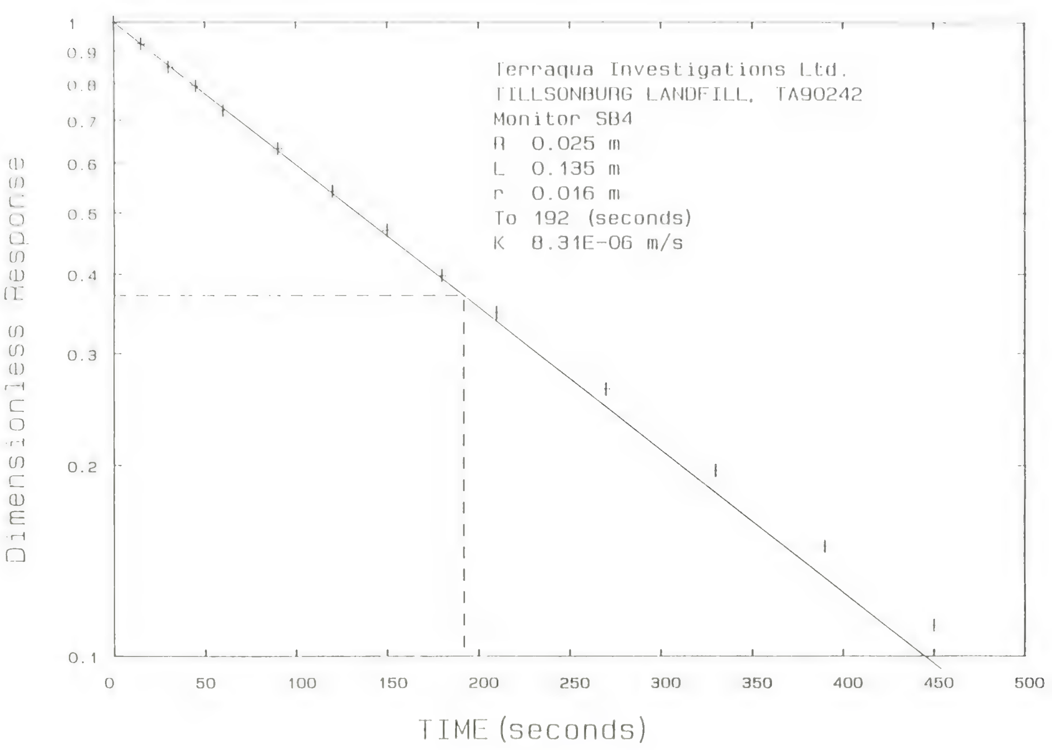
RESPONSE TEST ANALYSIS



RESPONSE TEST ANALYSIS



RESPONSE TEST ANALYSIS



APPENDIX E

Calculations

AVERAGE HYDRAULIC CONDUCTIVITY CALCULATION

MONITOR	K (m/s)	
OW1	6.08×10^{-6}	
2	1.92×10^{-5}	
4	5.20×10^{-6}	Geometric mean = 5.24×10^{-6} m/s
5	5.34×10^{-6}	
6	5.72×10^{-6}	
SB1	4.81×10^{-6}	
2	6.29×10^{-7}	Geometric mean = 3.56×10^{-6}s m/s
3	6.38×10^{-6}	
4	8.31×10^{-6}	

HORIZONTAL GRADIENT CALCULATION

for dh = 1m

dl ranges from 15m along bank to east
to 40m along bank to north
to 80m along south edge of landfill

Therefore i = dh/dl i = 1m/15m = 0.067 along bank to east
to i = 1m/40m = 0.025 along bank to north
to i = 1m/80m = 0.013 along bank to edge

AVERAGE LINEAR VELOCITY CALCULATION

$V = Ki/n$ where $n = 0.3$ (30%)

$k = 5.24 \times 10^{-6}$ m/s

i ranges from 0.067 (bank to east)
to 0.025 (bank to north)
to 0.013 (south edge)

VELOCITY RANGES FROM

$V = (5.24 \times 10^{-6}\text{ m/s})\ (0.067)/(0.3)$ $= 1.17 \times 10^{-6}$ m/s

= 40 m/yr along bank to east

to $V = (5.24 \times 10^{-6}\text{ m/s})\ (0.025)/(0.3)$ $= 4.37 \times 10^{-7}$ m/s

= 14 m/yr along bank to north

to $V = (5.24 \times 10^{-6}\text{ m/s})\ (0.013)/(0.3)$ $= 2.27 \times 10^{-7}$ m/s

= 7 m/yr along south edge

landfill has been present 1971 to 1991 = 20 years

Therefore groundwater movement between 140 to 800 metres.

VOLUMETRIC FLUX CALCULATION

To estimate flux coming onto and leaving site (towards stream) divide site into 3 "cells" 1, 2, and 3 (see Figure E1)

FLUX ONTO SITE

A) Estimate Saturated Thickness Along Upgradient Edge of Cells (from September 10, 1990)

@ OW1 – 4.0 m	
@ OW4 – 3.6 m	use 4.0 m as average thickness
@ OW2 – 3.1 m	

B) Calculate Saturated Cross-Sectional "Areas" of Cells

CELL	UPGRADIENT EDGE LENGTH	AREA
1	173 m	692 m^2
2	70 m	280 m^2
3	43 m	172 m^2
	286 m	1144 m^2

C) Estimate Horizonal Gradient at Upgradient Edge

CELL	dh	dl	i
1	2m	87m	2.3×10^{-2}
2	2m	177m	1.1×10^{-2}
3	2m	183m	1.1×10^{-2}

VOLUMETRIC FLUX CALCULATION

FLUX ONTO SITE

D) $Q = KiA$ (assume $K = 5.24 \times 10^{-6}$ m/s)

CELL	K(m/s)	i	A (m²)	Q(m³/s)	Q(m³/yr)
1	5.24×10^{-6}	2.3×10^{-2}	692	$8.3 \times 10^{-}$	2600
2	5.24×10^{-6}	1.1×10^{-2}	280	1.6×10^{-5}	510
3	5.24×10^{-6}	1.1×10^{-2}	172	9.9×10^{-6}	310
					3420 m³/yr.

Therefore TOTAL IN–FLUX = 3420 m³/year = 3,400,000 L/yr

VOLUMETRIC FLUX CALCULATION

FLUX OFF OF SITE

1. Saturated Thickness – Downgradient Edge (September 10/90)

@ OW 6 – 2.4 m   Use 3.4 m for Cell 1

@ OW 5 – 3.4 m   2.4 m for Cells 2 and 3

2. Saturated Areas

CELL	DOWNGRADIENT EDGE LENGTH	AREA
1	150 m	510 m^2
2	140 m	340 m^2
3	90 m	220 m^2

3. Horizontal Gradient

CELL	dh	dl	i
1	2m	65m	3.1×10^{-2}
2	2m	57m	3.5×10^{-2}
3	2m	48m	4.2×10^{-2}

4. Q = KiA

CELL	K (m/s)	i	A(m^3)	Q(m^3/s)	Q(m^3/yr)
1	5.24×10^{-6}	3.1×10^{-2}	510	8.3×10^{-5}	2600
2	5.24×10^{-6}	3.5×10^{-2}	340	6.2×10^{-5}	2000
3	5.24×10^{-6}	4.2×10^{-2}	220	4.8×10^{-5}	1500
					6100 m^3/yr.

Therefore TOTAL OUT–FLUX = 6100 m^3/yr = 6,100,000 L/yr.

Difference Between influx and outflux = 2,700,000 L/yr.

RECHARGE (TO SITE) CALCULATION

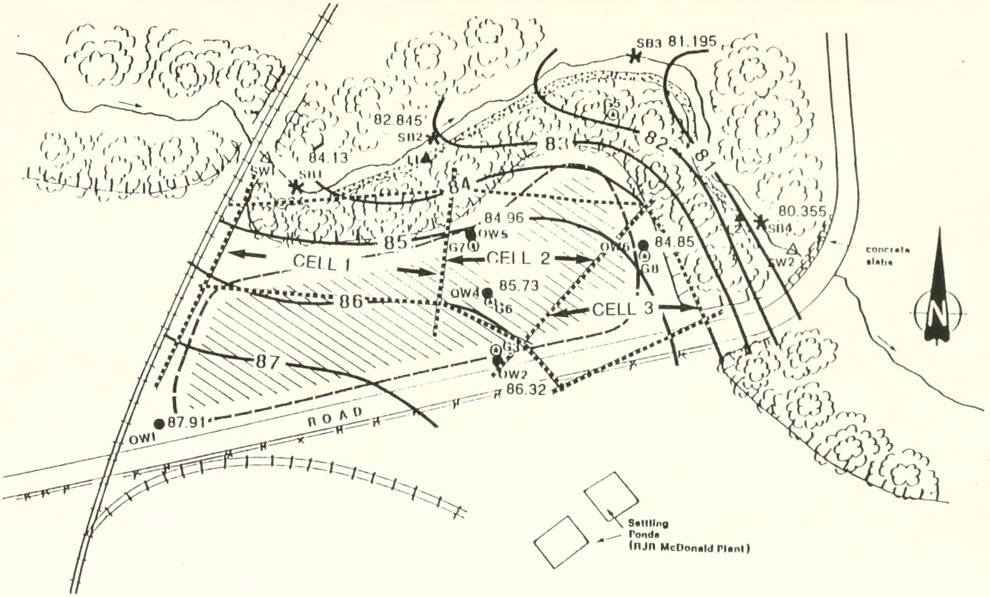
Calculate recharge to Cells to check on Flux difference.

Calculated Flux Difference = 2,700,000 L/yr
= 2,700 m^3/yr

Therefore infiltration rate on the order of

$$2{,}700\ m^3/yr\ /\ 30{,}000\ m^2 = 0.09\ m^3/yr/m^2$$

This infiltration rate seems reasonable for clay cover considering evapotranspiration losses due to corn cultivation.



LEGEND

OW1 ●	Groundwater Monitor	○	**Proposed location** OW3
		▭	Approx. extent of landfill
SB1 ★	Streambed Piezometer	▨	Cultivated field
G3 ⊛	Gas Probe		Wooded area
L1 ▲	Leachate Sample		Steep embankment
SW1 △	Surface Water Sample		Zone of seepage

SCALE

0 50 100 metres

PROJECT TA90242
TILLSONBURG CLOSED LANDFILL
HYDROGEOLOGIC STUDY
MINISTRY OF THE ENVIRONMENT

FIGURE E1